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ABSTRACT

This study is the sixth in the series "Studies in the Phonology of Asian Languages." A phonetic and phonemic analysis of the three complex nuclei of Vietnames (Hanoi dialect), spelled (1) ye-, -ie-, -ia, (2) -u'o'-, -u'a, and (3) -uo-, -ua, was carried out using the sound spectrograph. The relative domains of the target qualities of the complex nuclei were established and then compared with those of the eleven simple vowels. Further analysis was done, varying the environment with regard to type of syllable, tone, and initial and final consonants. Regardless of environment, a relative distincitiveness of domain seems to be maintained. (Author/DD)

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STUDIES IN THE PHONOLOGY OF ASIAN LANGUAGES

VI

# COMPLEX SYLLABLE NUCLEI IN VIETNAMESE

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# PREFACE

This study, Complex Syllable Nuclei in Vietnamese, is the sixth publication in the series Studies in the Phonology of Asian Languages. It is a result of a research project sponsored by the Office of Naval Research, whose financial support of the project is gratefully acknowledged. This volume serves as a technical report for the contract NR 049-183, Nonr 228(28).

The first volume of the series, Acoustic Phonetics of Korean, Technical Report No. I, was devoted to the acoustic-phonetic study of Korean vowels. The second volume was Duration of Korean Vowels; the third, Acoustic Characteristics of Korean Stop Consonants; the fourth, Vietnamese Vowels; and the fifth, Acoustic Features in the Manner-Differentiation of Korean Stop Consonants. The present volume, VI, is devoted to the study of complex syllable nuclei in Vietnamese. Studies on other phonological features of Korean, Vietnamese, and other Asian languages are in progress and the results will be reported in the near future.

Much of the experimental work of this study was carried out by Michael Earle, while the editorial work was done by Haruo Furukawa and Sylvia Buck.

Mieko S. Han

Los Angeles, California

January 1968

TABLE OF CONTENTS

PREFACE . . . . . ii

1. PROBLEMS IN THE ANALYSIS OF VIETNAMESE COMPLEX SYLLABLE NUCLEI . . . . . 1

2. MATERIALS AND TECHNIQUE . . . . . 7

Informants

Tape Recordings

The Spectrograph and Spectrograms

Formants and Formant Measurement

Amplitude

3. TARGET QUALITIES OF COMPLEX NUCLEI . . . . . 13

4. COMPLEX NUCLEI IN VARIED ENVIRONMENTS . . . . . 51

CONCLUSION . . . . . 92

Chapter 1

# PROBLEMS IN THE ANALYSIS OF VIETNAMESE COMPLEX SYLLABLE NUCLEI

In volume IV of this series, Studies in the Phonology of Asian Languages: Vietnamese Vowels, the eleven simple vowel phonemes of the Hanoi dialect of Vietnamese were studied and described. Formant 1 and Formant 2 of the eleven vowels were measured and analysed; the domains of the vowel phonemes relative to one another were studied; tonal and consonantal influences on vowel quality were noted; and a study on the inherent duration of each of the eleven vowels was carried out.

The eleven simple vowels occur as syllable nuclei carrying one of the six phonemically distinct tones. In addition to these simple vowels, there are certain other sequences which also occur as syllable nuclei. Such sequences are found in the following examples.

1) The sequences spelled:

| | | | |
|---|---|---|---|
| yê- | as in | "yêm" | (to salt or pickle) |
| -iê- | as in | "tiên" | (immortal) |
| -ia | as in | "tia" | (jet; ray) |

These three sequences all seem to have similar phonetic qualities in that they all sound like a high front unrounded vowel [i] which changes to a mid front vowel slightly more

centralized than [e]. This sequence is tentatively transcribed [Iɜ].

2) The sequences spelled:

-ưở- as in "tưởng" (bean sauce)

-ưa as in "tựa" (preface)

These two sequences both sound like a high central unrounded vowel [ɯ] which moves to a mid central unrounded vowel. Our tentative phonetic symbolization for this sequence is [ɯɨ].

3) The sequences spelled:

-uô- as in "tuôn" (to throng)

-ua as in "tua" (fringe)

These two sequences both sound like a high back rounded vowel [u] which moves to a mid back vowel slightly more centralized than [o]. Our phonetic symbolization for this sequence is [Uθ].

The first segments of each of these sequences [Iɜ], [ɯɨ], and [Uθ] have been analysed as /i/ /ɯ/ and /u/ by most analysts who have worked on Vietnamese phonology, but the second segments have caused disagreement. Auditory impressions of [ɜ], [ɨ], and [θ] vary depending on the hearer's own speech background. The American English speaker tends to hear all three as something like schwa [ə], while speakers of other language backgrounds may hear something else.

These three complex syllable nuclei are heard as being distinctly different from the combination of a vowel plus a semivowel. The stress on the second element of the sequences,

[Iɜ], [ɯɪ], and [Uθ], is heard as being at least equal to the stress on the first element. This suggests the presence of two target vowel qualities rather than a vowel plus a semivowel.

With regard to articulatory characteristics, all three sequences have tongue movement from higher to lower position. It is observed that the second segment of [Iɜ] is pronounced with the lips noticeably less spread than they are for [e]. The second segment of [Uθ] has much less lip rounding than [o].

The several analysts who have worked on Vietnamese phonology disagree in the analysis of these three complex syllable nuclei. The analyses of Nguyễn Đình Hoà, Lê-Văn-Lý, Murray B. Emeneau, and Laurence C. Thompson concerning the complex syllable nuclei in Vietnamese are summarized in the following paragraphs. It will be noted that their interpretations vary considerably. Only those portions of their works which deal explicitly with the phonemic analysis of the problem are presented here. One liberty which has been taken in presenting their analyses is the modification of their phonemic notation to make it conform to that used in this work. This was done to facilitate the understanding of the points of difference between these analysts and to enable one to compare their analyses.

Hoà[1] analyses the above mentioned complex nuclei as "vowel clusters" that are composed of /i/, /ɯ/, /u/ plus the

---

[1]Nguyễn Đình Hoà, Speak Vietnamese (Rev. ed.; Rutland & Tokyo: Charles E. Tuttle Co.: Publishers, 1966).

phoneme /ʌ/. Therefore,

"tiên" is analysed as /tiʌn/

"tươh" is analysed as /tɯʌn/

"tuôn" is analysed as /tuʌn/

According to Hoà's analysis, the second segment of each of the three complex nuclei is regarded as being the same phoneme [ʌ] in all three cases.

Emeneau's analysis[1] is similar to that of Hoà's. Emeneau describes the clusters in question as involving movement from the higher vowels /i, ɯ, u/ to /ʌ/. He interprets the clusters phonetically as [iʌ̯][2], [ɯʌ̯], and [uʌ̯] and phonemically as /iʌ/, /ɯʌ/, and /uʌ/, respectively.

On the other hand, Lê-Văn-Lý[3] analyses the sequences as [ie], [ɯə], and [uo] and stresses the "monophonematic" character of the sequences, saying that the two constituent elements [i] and [e], [ɯ] and [ə], and [u] and [o] are indissociable, thus proving that they are single phonemes. This makes the total inventory of Vietnamese vowels as follows:

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[1]Murray B. Emeneau, "Studies in Vietnamese (Annamese) Grammar," University of California Publications in Linguistics, VIII (1951), 10ff.

[2][ʌ̯] = unstressed [ʌ]

[3]Lê-Văn-Lý, Le Parler Vietnamien (2nd ed.; Saigon: Bộ Quốc-Giá Giáo-Duc, 1960).

| | | |
|---|---|---|
| /i/ | /ɯ/ | /u/[1] |
| /ie/ | /ɯə/ | /uo/ |
| /e/ | /ə/ | /o/ |
| /ɛ/ | /ʌ/ | /ɔ/ |
| | /A/ /a/ | |

Laurence C. Thompson[2] views a "vowel cluster" as that which contains two dissimilar vowels in sequence, neither of which is enough less prominent than the other to qualify as a semivowel. In Thompson's analysis the sequences spelled "-ia," "-uơ," "-ua" in final position are /i, ɯ, u/ followed by /ʌ/, while the sequences spelled "-iê-," "-ươ-," "-uô-" in medial postion are /i/ + /e/, /ɯ/ + /ə/, and /u/ + /o/, respectively.

The main point of disagreement in the various analyses seems to spring from the varying interpretations of the <u>phonetic</u> quality of the second segment in question. The first question is, then, are the sequences [Iʒ], [ɯɪ], [Uθ] three separate phonetic movements from three high vowels to three mid vowels as diagramed below,

| | | |
|---|---|---|
| I | ɯ | U |
| ↓ | ↓ | ↓ |
| ʒ | ɪ | θ |

---

[1]Note that this table is from Văn-Lý, <u>Le Parler Vietnamien</u>, pp. 43-44, but the symbols have been changed to follow those used in this study.

[2]Laurence C. Thompson, <u>A Vietnamese Grammar</u> (Seattle: University of Washington Press, 1965), pp. 30ff.

or are the three segments tentatively described as [ɜ], [ɨ], [ɵ] phonetically similar enough to be interpreted as one mid central vowel [ə], as the following diagram shows?

Also, are the differences between the sequences spelled -ia, -u̯a, and -ua in open syllables and those spelled -iê-, -uo̯-, and -uô- in closed syllables so great that they should be considered as two different syllable nuclei, or is the difference a conditioned one?

In order to arrive at a satisfactory phonetic and phonemic interpretation of these complex nuclei, techniques of acoustic-phonetic analysis with the aid of the sound spectrograph were applied. In this way the impressions based on hearing were re-examined and re-evaluated. Data obtained by the spectrograph offer objective facts concerning speech sounds, while human interpretation of these sounds is often subjective, being influenced by the speaker's language background.

The major part of investigation of this study will be concerned with determining the target qualities of the complex nuclei segments, i.e., whether or not the second segments of these nuclei are actually all one vowel or three different vowels, and what are the conditioned variants, if any.

After a careful examination a phonemic interpretation of the complex nuclei will be proposed.

## Chapter 2

## MATERIALS AND TECHNIQUE

This chapter describes briefly the materials and technique used in the analysis, the results of which will be described in subsequent chapters.

### Informants

The four informants who supplied data for analysis are the same as those who assisted in our previous study of Vietnamese Vowels, Vol. IV of this series. Biographical sketches of these informants are briefly presented here.

Informant 1 Nguyễn Hữu Quảng--male, age 30, was born in Haiphong and lived 18 years in Hanoi. He moved to South Viet Nam in 1954 and there attended the University of Saigon. From 1962 through 1965, he resided, as a student, in the United States. His native language is the Hanoi dialect of Vietnamese and he is also fluent in French and English. QUANG believes that his residence in the Saigon dialect area has not affected his speech, as his language habits were already well established by the time he moved to South Viet Nam.

Informant 2 Pham Gia Huấn--male, age 21 , was born in the the vicinity of Hanoi. His family moved to Paris, France, at

the time he entered primary school. Though his formal education was conducted in French, Vietnamese was used at home and with friends. His parents were born in Hanoi and lived there until they moved to Paris. He returned to Saigon for his secondary school education and resided there for seven years before coming to the United States in 1962. HUAN speaks both the Hanoi and Saigon dialects but distinguishes the two. According to another native speaker of the Hanoi dialect, the Saigon dialect has not affected HUAN's original Hanoi dialect.

Informant 3 Pham Thị-Ánh Tuyết--female, age 22, sister of HUAN, was born in the vicinity of Hanoi. She had one year of school there before going to Paris with her family. French was used in her formal education, and Vietnamese was used at home. Her secondary education was received at a French school in Saigon where she lived for several years before coming to the United States in 1962. In addition to the Hanoi dialect, she speaks the Saigon dialect, French, and English; but, she feels that her Hanoi dialect is not affected by these other languages.

Informant 4 Phàm Van Đồng--male, age 22 , is not related to HUAN and TUYET. His parents came from North Viet Nam, and the Hanoi dialect was always used in his home. For business reasons his family moved frequently around Northern and Central Viet Nam. DONG was born in Đa Nang but moved early in his life to the North. His elementary and high school education was received in either Vietnamese or French, according to the

school attended. DONG attended the University of Saigon for one year and came to the United States in 1962. Because of his frequent changes of residence, DONG is familiar with the Huế and Saigon dialects of Vietnamese, in addition to the Hanoi dialect; but, he regards the latter as his native dialect and feels that he clearly distinguishes the three. He is also fluent in French and English.

Tape Recordings

The prepared scripts were recorded by the informants in a sound proof booth using an AKG C-60 condenser microphone with a pre-amplifier and an Ampex PR-10 single-track tape recorder. Speech was recorded on Scotch or Ampex magnetic tape at a speed of 7.5 inches per second.

Since the informants were experienced in making tape recordings, they were relaxed and relatively at ease in front of the microphone. They were asked to use their normal speech tempo and to pronounce the words as they used them in their everyday speech. As the informants had assisted in drafting the recording scripts, the material was in their own handwriting and they had a certain degree of familiarity with the content of each script. This familiarity enabled them to read smoothly and without hesitations, lapses, or errors. As a part of each recording session, the informants listened to the tapes that they had recorded, checking the script as they listened. This ensured that each utterance recorded passed

the test of acceptability to the native speaker.

The Spectrograph and Spectrograms

An Ampex PR-10 single-track tape recorder was used to reproduce the recorded speech which was channeled directly into a modified model 661A Sound Spectrograph (Kay Sona-graph).

The sound spectrograph is a device which can analyse a sound segment of up to 2.4 seconds in duration. The sound segment is recorded on a disc inside the machine which repeats it constantly while a band-pass filter scans it, moving up the frequency scale from zero to 8000 cycles per second.

The signal from the scanning filter is transmitted to a stylus which is in contact with specially sensitized paper attached to a revolving drum. The resulting artifact is called a sound spectrogram and is a permanent record of the recorded speech segment. The spectrogram shows frequency in the vertical dimension, duration in the horizontal dimension, and gives a rough indication of intensity by the relative darkness of various portions of the spectrogram.

The spectrogram can be made with the band-pass filter set at either 45 or 300 cycles per second which produces narrow-band and wide-band spectrograms, respectively. It is also possible on this machine to record the portion from 0 to 4000 cps twice, one above the other, once with narrow-band and once with wide-band. As the essential features of vowels are realized in this frequency range and as each band-width has

certain advantages, composite spectrograms were most frequently used in this study.

Formants and Formant Measurement

Vowels are characterized by their relatively great resonance compared to consonants. This resonance is strengthened in various areas according to the configurations of the articulatory organs characteristic of each speech sound. These areas of strengthened resonance are called FORMANTS. Each vowel has a characteristic formant pattern, and it has been demonstrated experimentally that the first two formants carry most of the information about the qualities of vowels. In this study, measurements of the first two formants are studied in detail.

While it is easier to identify formants on a wide-band spectrogram, it is possible to be more accurate in the measurement of narrow-band spectrograms. This is the chief benefit of the composite spectrogram.

The procedure for measurement is to measure from the zero line, which is a part of every spectrogram, to the exact center of the formant. On a good narrow-band spectrogram, it is possible to measure reliably to within ±25 cps. In almost all cases, it is possible to measure to within ±50 cps.

The steady state of a vowel is defined as that portion of the vowel in which the formants are parallel to the zero line. When there is a steady state of a vowel present, measurements are made at that point in time. Movements of formants

associated with initial and final consonants are called TRANSITIONS. Typically, there is a transition from an initial consonant to the steady state of the vowel and a transition from the steady state of the vowel to the final consonant. In some cases there is no steady state of the vowel since the transition from the initial consonant through the vowel to the final consonant is continuous. In this case the mid-point of the vowel is arbitrarily selected as the point of measurement on the assumption that, at this point, the effect of the initial and final transitions cancel each other out.

Amplitude

The Kay Sona-graph comes with an attachment for measuring and recording on a spectrogram the amplitude contour of a given utterance of up to 2.4 seconds in duration. This contour appears in reference to a base line on the upper portion of the spectrogram. However, there are many factors affecting the amplitude display and care must be taken to avoid invalid comparisons between two amplitude contours.

For our purposes, the amplitude display was referred to only as an aid in distinguishing the most prominent segment of the syllable and in comparing the relative amplitudes of different portions of a single syllable.

## CHAPTER 3

## TARGET QUALITIES OF COMPLEX NUCLEI

To provide a basis for the analysis of the complex nuclei [Iɜ], [ɯɨ], and [Uɵ], the eleven simple vowels of each informant were re-examined. Our previous study revealed that vowel formant measurements are influenced considerably by neighboring consonants and the accompanying tone. We, therefore, obtained measurements of the eleven simple vowels in a fixed environment which could serve as the basis for comparison with the complex nuclei. Any two phonemically identical sounds may differ phonetically even in the same environment; but, if the environment is specifically limited, similar phones will recur within a small domain definable by a boundary. In the analysis that follows, the relative domains of the eleven simple vowels and also the relative domains of the vowel target qualities of the complex nuclei were obtained. These were then compared with each other to determine the phonetic qualities of the complex nuclei in question.

The eleven simple vowels and three complex nuclei were recorded in the environment /t - n/ with level tone /-/ by the informants. This phonetic environment was selected for several reasons. First, /n/ and /t/ are the only consonants which can

occur after every vowel; and, /n/ was preferred to /t/ because /t/ occurs only with rising tone /ˊ/ and drop tone /ˌ/, while /n/ occurs with all six tones. The initial consonant /t/ was then selected because most of the /t - n/ syllables form real words in the Vietnamese language. These syllables were therefore familiar to the informants and could be spoken without hesitation.

The frame sentence "I say the word ( ); ( ), ( ), ( )." was used, the test word being uttered four times; e.g., /tōy dɔ̄k cw̃ tān; tān, tān, tān./ Narrow-band spectrograms were made of five recordings, resulting in 20 sets of Formant 1 and Formant 2 measurements for each vowel. These measurements were then plotted on a formant chart to establish the domain of each of the simple vowel phonemes. The same procedure was followed in making spectrograms, measurements, and charts for the complex syllable nuclei. Then the charts of the complex nuclei were compared to the charts of the simple vowels.

Because Informants 1 and 2 left us before the experiments had been completed, only a limited number of their recordings and spectrograms were available. Informants 3 and 4 furnished most of the data used in this analysis.

Table 1 shows the formant measurements of the eleven simple vowels of Informant 4 in the environment /t - n/ with level tone.

Figure 1 is the corresponding representation on the formant chart of the F1 and F2 measurements presented in Table 1.

The domain of each vowel is represented by twenty occurrences of that vowel in the environment indicated. The formant chart used in this study is the same as that used in our previous study, Vol. IV of this series. The reason for the choice of this formant chart was explained on pp. 69-72 of Vol. IV.

Table 2 represents the F1 and F2 measurements of the eleven vowels of Informant 3 in the environment /t - n/ with level tone. As is known to most workers in acoustic phonetics, it is quite difficult to obtain accurate formant measurements of a female voice since a soprano or alto voice has wide formant bands and widely spaced harmonics which make it difficult to identify the exact frequency value of the formants. To overcome these difficulties and to reduce marginal errors, a large amount of data was utilized and extra care was taken in measuring.

Figure 2 represents the domains on the formant chart of the eleven vowels in the environment /t - n/ with level tone spoken by Informant 3.

As can be seen in Figure 2, the domains of Informant 3's vowels cover a much greater area than do those of Informant 4. Given the above-mentioned characteristics of the female voice, this is to be expected. However, in order to show that these domains are truly representative, we prepared additional material to show the effect of the six tones on the formant measurements of vowels in isolation and, also, material to show the effect of initial consonants on vowel formants.

TABLE 1

Formant measurements of simple vowels in the environment /t - n/: Informant 4 cycles/second

Vowel [i] with tone [-]

| Word | 1 F1 | F2 | F3 | 2 F1 | F2 | F3 | 3 F1 | F2 | F3 | 4 F1 | F2 | F3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| tīn | 300 | 2550 | 3100 | 300 | 2500 | 3050 | 300 | 2300 | 3100 | 300 | 2250 | 3000 |
| | 300 | 2400 | 3200 | 300 | 2350 | 3150 | 300 | 2250 | 3100 | 300 | 2350 | 3100 |
| | 300 | 2400 | 3100 | 300 | 2300 | 3200 | 325 | 2350 | 3000 | 300 | 2250 | 3000 |
| | 300 | 2450 | 3150 | 325 | 2350 | 2950 | 350 | 2300 | 3050 | 325 | 2300 | 3000 |
| | 300 | 2350 | 3000 | 300 | 2350 | 3000 | 300 | 2350 | 3050 | 300 | 2250 | 3000 |

Vowel [e] with tone [-]

| Word | 1 F1 | F2 | F3 | 2 F1 | F2 | F3 | 3 F1 | F2 | F3 | 4 F1 | F2 | F3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| tēn | 600 | 2100 | 2850 | 550 | 2050 | 3000 | 550 | 2000 | | 600 | 2000 | |
| | 550 | 2100 | 2850 | 550 | 2050 | 2900 | 550 | 2100 | 2800 | 600 | 2000 | 2800 |
| | 650 | 2100 | 2800 | 625 | 2100 | 2850 | 650 | 2100 | 2800 | 650 | 2000 | 2850 |
| | 600 | 2100 | 2850 | 600 | 2100 | 2800 | 600 | 2100 | | 600 | 2000 | 2800 |
| | 650 | 2150 | 2900 | 650 | 2100 | 3000 | 650 | 2100 | 2950 | 650 | 2050 | 2800 |

Vowel [ɛ] with tone [-]

| Word | 1 F1 | F2 | F3 | 2 F1 | F2 | F3 | 3 F1 | F2 | F3 | 4 F1 | F2 | F3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| tɛ̄n | 700 | 2000 | 2900 | 700 | 1900 | 2800 | 700 | 1900 | 2850 | 700 | 2000 | 2900 |
| | 750 | 2000 | 2850 | 700 | 2050 | 2950 | 700 | 2000 | 2950 | 750 | 1900 | 2800 |
| | 700 | 1900 | 2850 | 750 | 1950 | 2850 | 700 | 2100 | 2850 | 700 | 1950 | 2800 |
| | 700 | 2000 | 2800 | 700 | 2000 | 2800 | 700 | 2000 | 2800 | 700 | 2000 | 2800 |
| | 750 | 2100 | 2850 | 750 | 1950 | 2800 | 750 | 2000 | 2850 | 750 | 1950 | 2800 |

Vowel [a] with tone [-]

| Word | 1 F1 | F2 | F3 | 2 F1 | F2 | F3 | 3 F1 | F2 | F3 | 4 F1 | F2 | F3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| tān | 900 | 1500 | | 900 | 1450 | | 900 | 1400 | | 900 | 1550 | |
| | 900 | 1550 | | 900 | 1500 | | 900 | 1450 | | 900 | 1450 | |
| | 900 | 1500 | | 900 | 1550 | | 900 | 1500 | | 900 | 1450 | |
| | 900 | 1550 | | 900 | 1500 | | 900 | 1450 | | 900 | 1500 | |
| | 900 | 1550 | | 900 | 1500 | | 900 | 1500 | | 900 | 1500 | |

Vowel [ʌ] with tone [-]

| Word | 1 F1 | F2 | F3 | 2 F1 | F2 | F3 | 3 F1 | F2 | F3 | 4 F1 | F2 | F3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| tʌ̄n | 825 | 1400 | | 825 | 1500 | | 825 | 1500 | | 850 | 1500 | |
| | 850 | 1400 | | 850 | 1400 | | 850 | 1450 | | 850 | 1450 | |
| | 850 | 1500 | | 850 | 1450 | | 850 | 1400 | | 850 | 1400 | |
| | 850 | 1500 | | 900 | 1400 | | 900 | 1500 | | 900 | 1500 | |
| | 900 | 1500 | | 850 | | | 900 | 1450 | | 900 | 1450 | |

Vowel [ʌ] with tone [-]

| Word | 1 F1 | F2 | F3 | 2 F1 | F2 | F3 | 3 F1 | F2 | F3 | 4 F1 | F2 | F3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| tʌ̄n | 750 | 1500 | | 775 | 1400 | | 750 | 1550 | | 750 | 1400 | |
| | 700 | 1500 | | 700 | 1450 | | 700 | 1450 | | 700 | 1400 | |
| | 750 | 1400 | | 750 | 1350 | | 750 | 1350 | | 750 | 1550 | |
| | 750 | 1400 | | 750 | 1350 | | 750 | 1350 | | 750 | 1400 | |
| | 750 | 1500 | | 750 | 1450 | | 750 | 1400 | | 750 | 1350 | |

Vowel [ə] with tone [-]

| Word | 1 F1 | F2 | F3 | 2 F1 | F2 | F3 | 3 F1 | F2 | F3 | 4 F1 | F2 | F3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| tə̄n | 650 | 1400 | | 600 | 1400 | | 625 | 1300 | | 600 | 1350 | |
| | 600 | 1400 | | 600 | 1350 | | 600 | 1250 | | 575 | 1350 | |
| | 650 | 1400 | | 625 | 1400 | | 600 | 1400 | | 650 | 1450 | |
| | 600 | 1400 | | 600 | 1400 | | 600 | 1400 | | 600 | 1350 | |
| | 600 | 1400 | | 600 | 1400 | | 600 | 1400 | | 600 | 1400 | |

Vowel [ɯ] with tone [-]

| Word | 1 F1 | F2 | F3 | 2 F1 | F2 | F3 | 3 F1 | F2 | F3 | 4 F1 | F2 | F3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| tɯ̄n | 500 | 1400 | 2800 | 500 | 1450 | 2800 | 475 | 1400 | 2800 | 500 | 1550 | 2850 |
| | 550 | 1500 | 2800 | 550 | 1400 | | 550 | 1450 | | 550 | 1450 | 2900 |
| | 550 | 1450 | 2900 | 550 | 1450 | 2900 | 550 | 1450 | 2850 | 550 | 1450 | 2900 |
| | 525 | 1400 | 2900 | 525 | 1450 | 2850 | 550 | 1400 | 2750 | 550 | 1450 | 2900 |
| | 550 | 1400 | 2900 | 550 | 1400 | 2800 | 550 | 1350 | 2950 | 550 | 1350 | 2850 |

Vowel [ɔ] with tone [-]

| Word | 1 F1 | F2 | F3 | 2 F1 | F2 | F3 | 3 F1 | F2 | F3 | 4 F1 | F2 | F3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| tɔ̄n | 700 | 1000 | | 700 | 950 | | 700 | 950 | | 700 | 1000 | |
| | 700 | 1050 | | 700 | 1100 | | 700 | 1050 | | 700 | 1000 | |
| | 700 | 1050 | | 700 | 1100 | | 700 | 1050 | | 700 | 1000 | |
| | 700 | 1100 | | 700 | 1000 | | 700 | 1050 | | 700 | 1050 | |
| | 750 | 1050 | | 750 | 1050 | | 750 | 1050 | | 750 | 1050 | |

Vowel [o] with tone [-]

| Word | 1 F1 | F2 | F3 | 2 F1 | F2 | F3 | 3 F1 | F2 | F3 | 4 F1 | F2 | F3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| tō̄n | 550 | 1100 | | 500 | 1000 | | 500 | 1100 | | 550 | 1100 | |
| | 500 | 1000 | | 500 | 1050 | | 550 | 1000 | | 550 | 1000 | |
| | 600 | 1050 | | 600 | 1050 | | 600 | 1050 | | 600 | 1050 | |
| | 600 | 1050 | | 600 | 1050 | | 600 | 1050 | | 575 | 1050 | |
| | 550 | 900 | | 550 | 950 | | 550 | 1000 | | 550 | 1000 | |

Vowel [u] with tone [-]

| Word | 1 F1 | F2 | F3 | 2 F1 | F2 | F3 | 3 F1 | F2 | F3 | 4 F1 | F2 | F3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| tū̄n | 300 | 800 | | 300 | 800 | | 300 | 800 | | 300 | 800 | |
| | 300 | 800 | | 325 | 800 | | 325 | 800 | | 350 | 800 | |
| | 300 | 800 | | 300 | 800 | | 300 | 800 | | 300 | 800 | |
| | 300 | 800 | | 300 | 800 | | 300 | 850 | | 300 | 850 | |
| | 300 | 800 | | 300 | 800 | | 300 | 800 | | 325 | 850 | |

Blank spaces indicate where precise measurements were not obtainable.

FIGURE 1

Simple vowels in the environment /t - n/

Level tone Informant 4

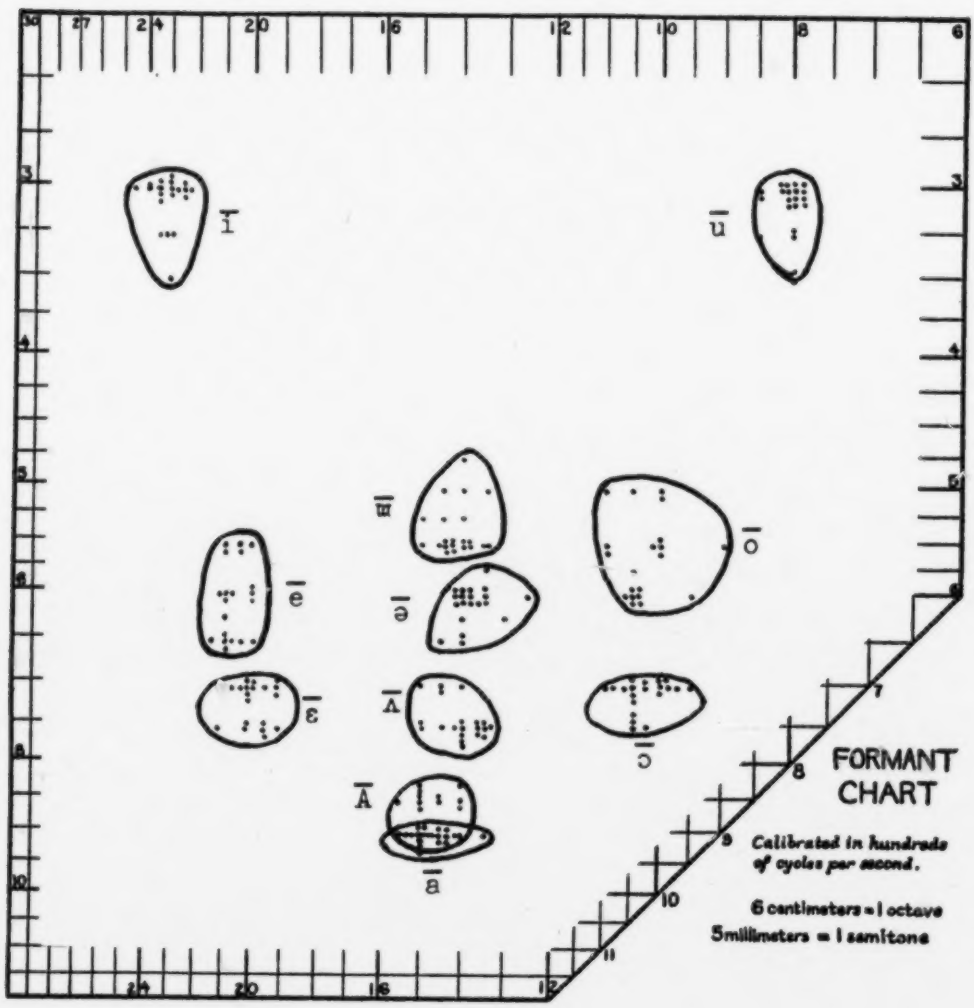


TABLE 2

Formant measurements of simple vowels in the environment /t - n/: Informant 3 cycles/second

Vowel [i] with tone [-]

| Word | 1 F1 | F2 | F3 | 2 F1 | F2 | F3 | 3 F1 | F2 | F3 | 4 F1 | F2 | F3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| tīn | 400 | 2650 | | 400 | 2850 | | 400 | 2750 | | 400 | 2800 | |
| | 400 | 2650 | | 400 | 2700 | | 400 | 2700 | | 400 | 2700 | |
| | 400 | 2700 | | 400 | 2700 | | 400 | 2750 | | 400 | 2750 | |
| | 400 | 2750 | | 400 | 2700 | | 400 | 2650 | | 400 | 2750 | |
| | 400 | 2800 | | 400 | 2750 | | 400 | 2700 | | 400 | 2700 | |

Vowel [e] with tone [-]

| Word | 1 F1 | F2 | F3 | 2 F1 | F2 | F3 | 3 F1 | F2 | F3 | 4 F1 | F2 | F3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| tēn | 550 | 2500 | 3050 | 550 | 2550 | | 550 | 2450 | | 550 | 2450 | 3000 |
| | 525 | 2450 | | 500 | 2550 | | 500 | 2500 | | 500 | 2550 | |
| | 525 | 2450 | | 500 | 2550 | | 525 | 2450 | | 500 | 2550 | |
| | 550 | 2450 | | 550 | 2400 | | 550 | 2400 | | 600 | 2400 | |
| | 550 | 2400 | | 525 | 2400 | | 500 | 2350 | | 550 | 2400 | |

Vowel [ɛ] with tone [-]

| Word | 1 F1 | F2 | F3 | 2 F1 | F2 | F3 | 3 F1 | F2 | F3 | 4 F1 | F2 | F3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| tɛ̄n | 800 | 2300 | 3200 | 750 | 2350 | 3100 | 775 | 2350 | 3150 | 800 | 2350 | 3150 |
| | 750 | 2350 | 3100 | 800 | 2350 | 3150 | 800 | 2450 | 3200 | 800 | 2300 | 3150 |
| | 800 | 2400 | | 800 | 2400 | 3150 | 800 | 2350 | 3150 | 800 | 2350 | |
| | 750 | 2350 | 3100 | 750 | 2400 | | 750 | 2350 | | 750 | 2400 | |
| | 750 | 2300 | | 750 | 2350 | | 775 | 2350 | | 800 | 2350 | |

Vowel [a] with tone [-]

| Word | 1 F1 | F2 | F3 | 2 F1 | F2 | F3 | 3 F1 | F2 | F3 | 4 F1 | F2 | F3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| tān | 950 | 1650 | | 950 | 1600 | | 1050 | 1600 | | 900 | 1650 | |
| | 1000 | 1650 | | 950 | 1600 | | 1000 | 1650 | | 900 | 1550 | |
| | 1000 | 1700 | | 1000 | 1700 | | 900 | 1700 | | 900 | 1700 | |
| | 950 | 1600 | | 1000 | 1650 | | 950 | 1700 | | 900 | 1600 | |
| | 950 | 1650 | | 950 | 1650 | | 900 | 1600 | | 900 | 1600 | |

Vowel [ʌ] with tone [-]

| Word | 1 F1 | F2 | F3 | 2 F1 | F2 | F3 | 3 F1 | F2 | F3 | 4 F1 | F2 | F3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| tʌ̄n | 850 | 1750 | | 850 | 1700 | | 850 | 1700 | | 800 | 1650 | |
| | 825 | 1650 | | 850 | 1750 | | 900 | 1750 | | 800 | 1600 | |
| | 900 | 1850 | | 900 | 1850 | | 900 | 1550 | | 800 | 1550 | |
| | 800 | 1850 | | 800 | 1650 | | 800 | 1600 | | 850 | 1750 | |
| | 825 | 1650 | | 800 | 1650 | | 800 | 1650 | | 800 | 1650 | |

Vowel [ʌ] with tone [-]

| Word | 1 F1 | F2 | F3 | 2 F1 | F2 | F3 | 3 F1 | F2 | F3 | 4 F1 | F2 | F3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| tʌ̄n | 850 | 1450 | | 800 | 1600 | | 800 | 1600 | | 800 | 1500 | |
| | 800 | 1650 | | 750 | 1500 | | 800 | 1600 | | 800 | 1550 | |
| | 800 | 1650 | | 800 | 1600 | | 750 | 1550 | | 800 | 1500 | |
| | 800 | 1650 | | 750 | 1550 | | 750 | 1550 | | 750 | 1600 | |
| | 800 | 1650 | | 750 | 1550 | | 750 | 1550 | | 800 | 1600 | |

Vowel [ə] with tone [-]

| Word | 1 F1 | F2 | F3 | 2 F1 | F2 | F3 | 3 F1 | F2 | F3 | 4 F1 | F2 | F3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| tə̄n | 700 | 1350 | | 700 | 1350 | | 650 | 1350 | | 650 | 1350 | |
| | 650 | 1350 | | 650 | 1350 | | 650 | 1350 | | 650 | 1350 | |
| | 700 | 1350 | | 650 | 1350 | | 650 | 1350 | | 650 | 1350 | |
| | 650 | 1350 | | 650 | 1350 | | 650 | 1300 | | 650 | 1300 | |
| | 600 | 1350 | | 650 | 1350 | | 650 | 1350 | | 650 | 1350 | |

Vowel [ɪ] with tone [-]

| Word | 1 F1 | F2 | F3 | 2 F1 | F2 | F3 | 3 F1 | F2 | F3 | 4 F1 | F2 | F3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| tɪ̄n | 450 | 1450 | | 550 | 1250 | | 550 | 1250 | | 550 | 1300 | |
| | 550 | 1350 | | 400 | 1250 | | 400 | 1250 | | 550 | 1350 | |
| | 550 | 1400 | | 550 | 1400 | | 550 | 1400 | | 525 | 1350 | |
| | 400 | 1450 | | 500 | 1350 | | 400 | 1200 | | 550 | 1200 | |
| | 500 | 1400 | | 550 | 1350 | | 550 | 1350 | | 525 | 1300 | |

Vowel [ɔ] with tone [-]

| Word | 1 F1 | F2 | F3 | 2 F1 | F2 | F3 | 3 F1 | F2 | F3 | 4 F1 | F2 | F3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| tɔ̄n | 800 | 1050 | | 750 | 1000 | | 800 | 1050 | | 750 | 1025 | |
| | 750 | 1050 | | 800 | 1050 | | 750 | 1025 | | 800 | 1050 | |
| | 800 | 1050 | | 750 | 1000 | | 750 | 1000 | | 750 | 1050 | |
| | 825 | 1100 | | 800 | 1050 | | 750 | 1050 | | 800 | 1050 | |
| | 800 | 1050 | | 750 | 1025 | | 750 | 1025 | | 750 | 1000 | |

Vowel [o] with tone [-]

| Word | 1 F1 | F2 | F3 | 2 F1 | F2 | F3 | 3 F1 | F2 | F3 | 4 F1 | F2 | F3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| tō̄n | 550 | 1100 | | 500 | 1000 | | 525 | 1000 | | 500 | 1000 | |
| | 500 | 1050 | | 525 | 1050 | | 500 | 1050 | | 500 | 1000 | |
| | 550 | 1050 | | 600 | 1050 | | 600 | 1000 | | 600 | 1050 | |
| | 525 | 1050 | | 525 | 1100 | | 650 | 1050 | | 525 | 1050 | |
| | 500 | 1050 | | 650 | 1050 | | 600 | 1000 | | 600 | 1050 | |

Vowel [u] with tone [-]

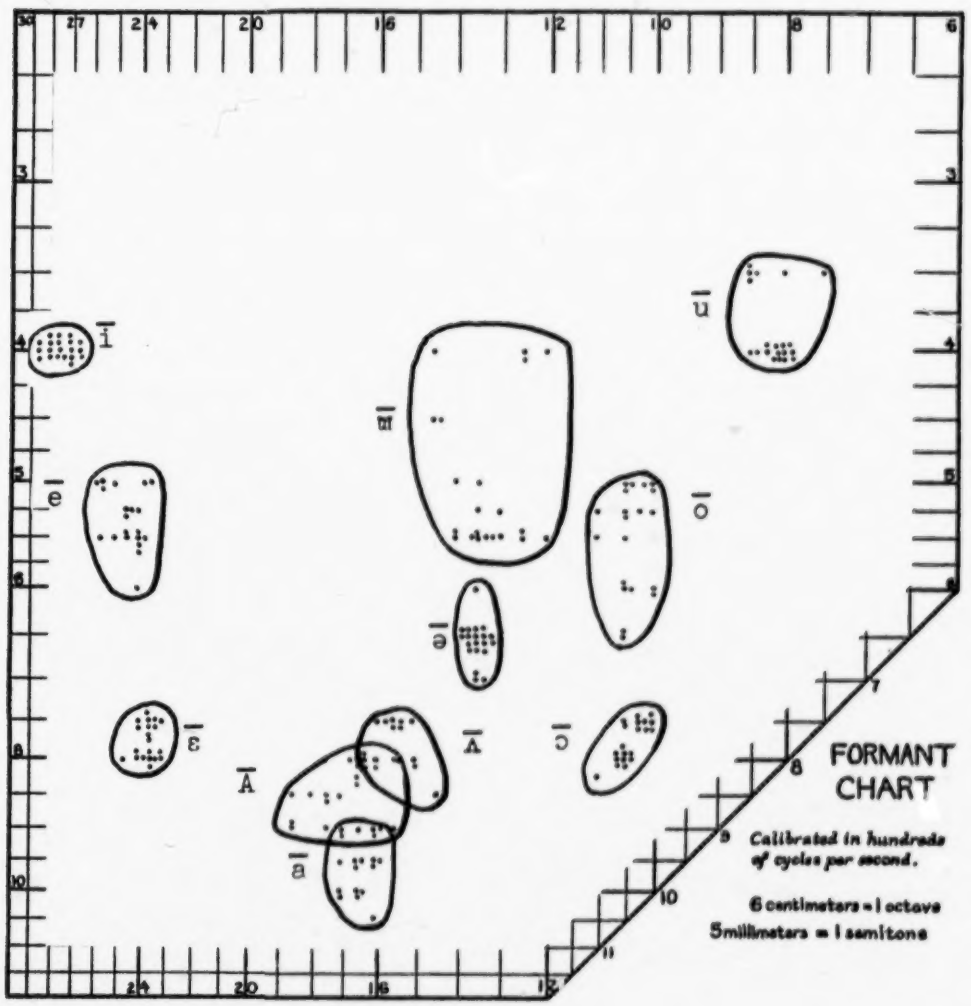
| Word | 1 F1 | F2 | F3 | 2 F1 | F2 | F3 | 3 F1 | F2 | F3 | 4 F1 | F2 | F3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| tŪn | 400 | 850 | | 400 | 825 | | 400 | 800 | | 400 | 800 | |
| | 350 | 850 | | 350 | 850 | | 350 | 850 | | 400 | 800 | |
| | 400 | 800 | | 400 | 825 | | 400 | 800 | | 400 | 800 | |
| | 350 | 800 | | 400 | 800 | | 350 | 750 | | 400 | 850 | |
| | 350 | 850 | | 400 | 800 | | 400 | 800 | | 400 | 800 | |

Blank spaces indicate where precise measurements were not obtainable.

FIGURE 2

Simple vowels in the environment /t - n/:

Level tone Informant 3



Informant 3 had previously made recordings of vowels in isolation with each of the six tones of Vietnamese. Although not all such isolated vowels are meaningful, this sort of exercise is quite common for students of Vietnamese. Since Informant 3 had often demonstrated these vowels and tones as a teacher of Vietnamese, she showed no hesitation in producing them for our study. Spectrograms were made from these recordings, and the F1 and F2 measurements were compiled.

Table 3 presents the F1 and F2 measurements of the vowels in isolation with each of the six tones. Figure 3 is the corresponding graphic representation of these F1 and F2 measurements on the formant chart.

In order to estimate the range of variation which might be associated with different initial consonants, Informant 3 was asked to record each vowel in various syllables composed of one initial consonant and the vowel with level tone. These syllables were recorded as a list of eighteen items in a fixed order, each stressed equally, e.g., /t$\bar{\imath}$, t$^{h}\bar{\imath}$, c$\bar{\imath}$, k$\bar{\imath}$ ..../ Table 4 represents the F1 and F2 measurements obtained from these recordings, and Figure 4 is the corresponding formant chart.

It must be noted that the two vowels /ʌ/ and /a/ occur only in closed syllables and so could not be included in this experiment. Figures 3 and 4 therefore present data for only 9 of the 11 simple vowels of Vietnamese.

TABLE 3

Formant measurements of simple vowels in isolation: Informant 3 cycles/second

Vowel [i] with all tones

| Word | 1 F1 | F2 | F3 | 2 F1 | F2 | F3 | 3 F1 | F2 | F3 | 4 F1 | F2 | F3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ī | 300 | 2950 | | 300 | 2750 | | 300 | 3000 | | | | |
| ǐ | 300 | 2900 | | 400 | 2850 | | 300 | 3100 | | 300 | 2800 | |
| ī | 275 | 2950 | | 275 | 2950 | | 275 | 2900 | | | | |
| í | 400 | 2800 | | 400 | 2900 | | 400 | 3050 | | | | |
| ì | 350 | 2850 | | 400 | 2750 | | 400 | 2850 | | | | |
| ī | 350 | 2900 | | 350 | 2950 | | 350 | 3000 | | | | |
| ī | 400 | 2950 | | 450 | 3000 | | 400 | 3050 | | | | |
| ī | 450 | 2800 | | 400 | 2850 | | 400 | 2800 | | | | |

Vowel [e] with all tones

| Word | 1 F1 | F2 | F3 | 2 F1 | F2 | F3 | 3 F1 | F2 | F3 | 4 F1 | F2 | F3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ē | | | | 900 | 2700 | | 900 | 2700 | | 900 | 2650 | |
| ē | | | | 850 | 2650 | | 850 | 2550 | | 850 | 2550 | |
| ē | 850 | 2600 | | 850 | 2650 | | 850 | 2550 | | | | |
| é | 850 | 2500 | | 750 | 2650 | | 750 | 2600 | | | | |
| è | 900 | 2450 | | 850 | 2500 | | 850 | 2500 | | | | |
| ē | 850 | 2400 | | 900 | 2500 | | 850 | 2450 | | | | |
| ē | 850 | 2500 | | 850 | 2450 | | 850 | 2550 | | | | |
| ē | 850 | 2500 | | 800 | 2400 | | 800 | 2450 | | | | |

Vowel [A] with all tones

| Word | 1 F1 | F2 | F3 | 2 F1 | F2 | F3 | 3 F1 | F2 | F3 | 4 F1 | F2 | F3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ā | | | | 850 | 1450 | | 850 | 1450 | | 900 | 1450 | |
| Ā | | | | 850 | 1600 | | 850 | 1700 | | 800 | 1650 | |
| Ā | 1150 | 1600 | | 1150 | 1600 | | 1000 | 1400 | | | | |
| Á | 950 | 1550 | | 950 | 1550 | | 900 | 1600 | | | | |
| À | 1000 | 1600 | | 1000 | 1450 | | 1050 | 1600 | | | | |
| Ā | 1050 | 1650 | | 1050 | 1600 | | 1050 | 1550 | | | | |
| Ā | 1000 | 1550 | | 950 | 1550 | | 950 | 1500 | | | | |
| Ā | 900 | 1500 | | 950 | 1500 | | 950 | 1500 | | | | |

Vowel [a] with all tones

| Word | 1 F1 | F2 | F3 | 2 F1 | F2 | F3 | 3 F1 | F2 | F3 | 4 F1 | F2 | F3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ā | 750 | 1300 | | 750 | 1250 | | 650 | 1250 | | | | |
| ā | 750 | 1550 | | 750 | 1300 | | 750 | 1300 | | | | |
| á | 750 | 1200 | | 750 | 1250 | | 700 | 1300 | | | | |
| à | 850 | 1300 | | 800 | 1250 | | 800 | 1200 | | | | |
| ā | 850 | 1250 | | 850 | 1250 | | 850 | 1200 | | | | |
| ā | 850 | 1350 | | 850 | 1350 | | 850 | 1400 | | | | |
| ā | 850 | 1300 | | 900 | 1400 | | 900 | 1400 | | | | |

Vowel [o] with all tones

| Word | 1 F1 | F2 | F3 | 2 F1 | F2 | F3 | 3 F1 | F2 | F3 | 4 F1 | F2 | F3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ō | 550 | 2600 | | 550 | 2750 | | 550 | 2700 | | | | |
| ō | 550 | 2850 | | 550 | 2700 | | 550 | 2750 | | | | |
| ó | 600 | 2650 | | 600 | 2650 | | 600 | 2650 | | | | |
| ò | 650 | 2450 | | 650 | 2600 | | 600 | 2650 | | | | |
| ō | 650 | 2550 | | 550 | 2450 | | 650 | 2550 | | | | |
| ō | 700 | 2600 | | 700 | 2550 | | 700 | 2650 | | | | |
| ō | 700 | 2550 | | 650 | 2600 | | 600 | 2550 | | | | |

Vowel [ɔ] with all tones

| Word | 1 F1 | F2 | F3 | 2 F1 | F2 | F3 | 3 F1 | F2 | F3 | 4 F1 | F2 | F3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ɔ | | | | 600 | 1250 | | 600 | 1250 | | 600 | 1250 | |
| ɔ | | | | 550 | 1200 | | 400 | 1150 | | 400 | 1150 | |
| ɔ | 450 | 1200 | | 450 | 1200 | | 450 | 1200 | | | | |
| ɔ́ | 525 | 1350 | | 525 | 1350 | | 525 | 1200 | | | | |
| ɔ̀ | 400 | 1250 | | 500 | 1300 | | 500 | 1350 | | | | |
| ɔ̄ | 450 | 1100 | | 500 | 1150 | | 500 | 1200 | | | | |
| ɔ̄ | 475 | 1450 | | 450 | 1350 | | 450 | 1350 | | | | |
| ɔ̄ | 550 | 1350 | | 600 | 1450 | | 600 | 1400 | | | | |

Vowel [o] with all tones

| Word | 1 F1 | F2 | F3 | 2 F1 | F2 | F3 | 3 F1 | F2 | F3 | 4 F1 | F2 | F3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ó | 600 | 1000 | | 600 | 1000 | | 550 | 1150 | | | | |
| ò | 650 | 1100 | | 600 | 1000 | | 600 | 1000 | | | | |
| ō | 550 | 950 | | 550 | 900 | | 600 | 850 | | | | |
| ō | 650 | 1100 | | 650 | 1150 | | 650 | 1100 | | | | |
| ō | 700 | 1000 | | 650 | 1000 | | 650 | 950 | | | | |
| ō | 650 | 1050 | | 650 | 1150 | | 525 | 1050 | | | | |
| ō | 650 | 1050 | | 550 | 1000 | | 500 | 1000 | | | | |
| ō | 650 | 1050 | | 600 | 1000 | | 500 | 1000 | | | | |
| ō | 500 | 1050 | | 500 | 1000 | | 500 | 1000 | | | | |
| ō | 500 | 1050 | | 500 | 1000 | | 500 | 1000 | | | | |
| ō | 550 | 1050 | | 600 | 1000 | | 525 | 1050 | | | | |

Vowel [u] with all tones

| Word | 1 F1 | F2 | F3 | 2 F1 | F2 | F3 | 3 F1 | F2 | F3 | 4 F1 | F2 | F3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ú | 400 | 1050 | | 400 | 1050 | | 400 | 1050 | | | | |
| ù | 400 | 850 | | 400 | 800 | | 350 | 750 | | | | |
| ū | 350 | 950 | | 350 | 900 | | 350 | 850 | | | | |
| ū | 450 | 900 | | 450 | 950 | | 450 | 900 | | | | |
| ū | 450 | 850 | | 400 | 850 | | 400 | 800 | | | | |
| ū | 300 | 900 | | 300 | 900 | | 300 | 950 | | | | |
| ū | 400 | 1000 | | 400 | 1100 | | 400 | 1000 | | | | |
| ū | 400 | 1000 | | 400 | 850 | | 400 | 850 | | | | |
| ū | 450 | 900 | | 450 | 900 | | 450 | 900 | | | | |
| ū | 300 | 900 | | 300 | 900 | | 300 | 850 | | | | |
| ū | 300 | 1000 | | 300 | 1000 | | 300 | 850 | | | | |
| ū | 400 | 1150 | | 450 | 1200 | | 450 | 1150 | | | | |
| ū | 300 | 1000 | | 300 | 850 | | 300 | 850 | | | | |

Vowel [ə] with all tones

| Word | 1 F1 | F2 | F3 | 2 F1 | F2 | F3 | 3 F1 | F2 | F3 | 4 F1 | F2 | F3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ə | 950 | 1150 | | 950 | 1200 | | 950 | 1150 | | | | |
| ə | 900 | 1500 | | 950 | 1250 | | 900 | 1250 | | | | |
| ə | 900 | 1100 | | 900 | 1100 | | 850 | 1150 | | | | |
| ə | 850 | 1100 | | 900 | 1150 | | 900 | 1150 | | | | |
| ə | 850 | 1250 | | 900 | 1200 | | 900 | 1200 | | | | |
| ə | 850 | 1150 | | 850 | 1150 | | 850 | 1100 | | | | |
| ə | | | | 900 | 1200 | | 850 | 1200 | | 850 | 1150 | |
| ə | | | | 850 | 1150 | | 850 | 1100 | | 850 | 1100 | |
| ə | 850 | 1100 | | 850 | 1250 | | 800 | 1100 | | 850 | 1100 | |
| ə | | | | 750 | 1000 | | 750 | 1000 | | 750 | 1000 | |
| ə | | | | 800 | 1050 | | 800 | 1050 | | 800 | 1050 | |
| ə | | | | 800 | 1100 | | 800 | 1050 | | 850 | 1100 | |
| ə | | | | 800 | 1050 | | 800 | 1050 | | 800 | 1050 | |
| ə | | | | 750 | 1050 | | 800 | 1050 | | 800 | 1050 | |
| ə | | | | 800 | 1050 | | 800 | 1050 | | 800 | 1050 | |
| ə | 800 | 1100 | | 750 | 1050 | | 750 | 1000 | | 750 | 1000 | |

Blank spaces indicate where precise measurements were not obtainable.

FIGURE 3

Simple vowels in isolation

All six tones Informant 3

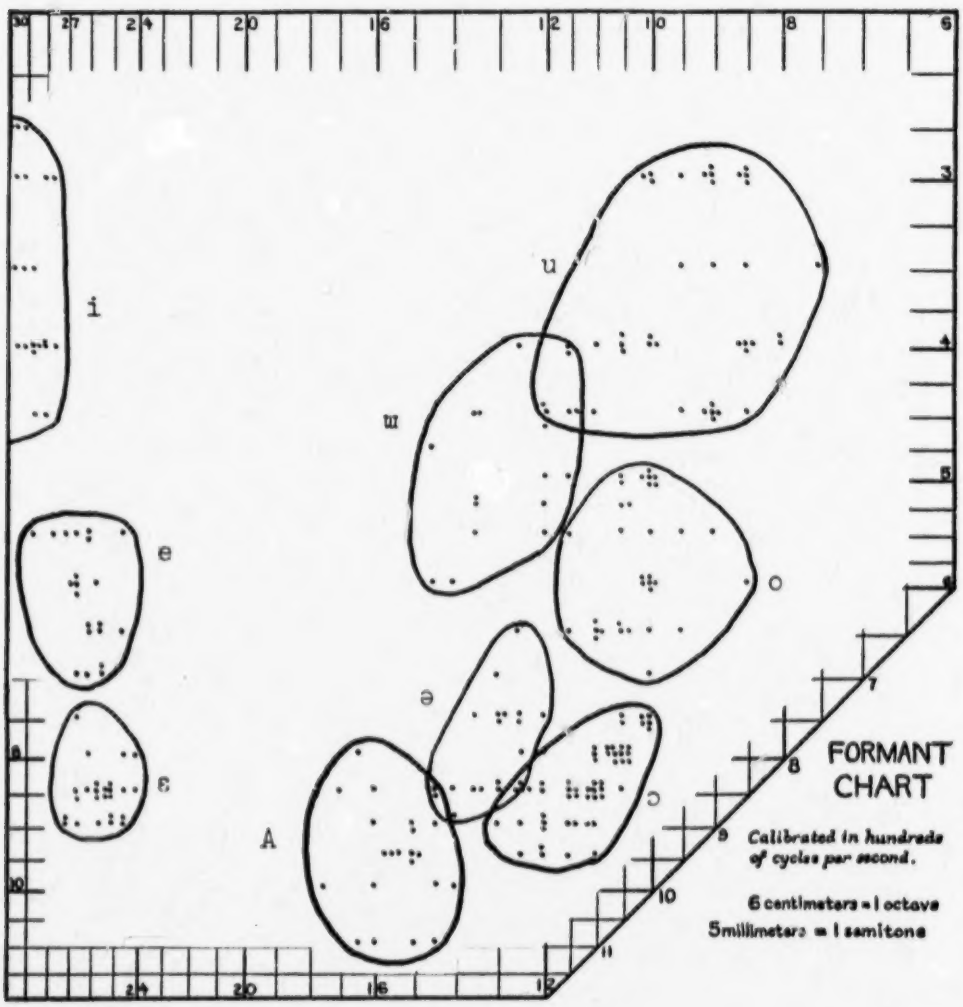


TABLE 4

Formant measurements of simple vowels in open syllables: Informant 3 cycles/second

Vowel [i] with tone [-]

| Word | F1 | F2 |
|---|---|---|
| tī | 300 | 2800 |
| tʰī | 275 | 2600 |
| cī | 400 | 2850 |
| kī | 300 | 2750 |
| bī | 300 | 2950 |
| dī | 275 | 2850 |
| fī | 250 | 2800 |
| vī | 250 | 2800 |
| sī | 400 | 2900 |
| zī | 300 | 2950 |
| xī | 250 | 2750 |
| gī | 400 | 2850 |
| mī | 400 | 2950 |
| nī | 300 | 2950 |
| ɲī | 350 | 2800 |
| ŋī | 350 | 2900 |
| hī | 275 | 2850 |
| lī | 350 | 2750 |

Vowel [e] with tone [-]

| Word | F1 | F2 |
|---|---|---|
| tē | 525 | 1350 |
| tʰē | 550 | 1350 |
| cē | 650 | 1300 |
| kē | 525 | 1300 |
| bē | 525 | 1300 |
| dē | 650 | 1400 |
| fē | 600 | 1350 |
| vē | 600 | 1300 |
| sē | 600 | 1400 |
| zē | 650 | 1600 |
| xē | 500 | 1350 |
| gē | 600 | 1500 |
| mē | 600 | 1300 |
| nē | 650 | 1450 |
| ɲē | 600 | 1500 |
| ŋē | 600 | 1500 |
| hē | 600 | 1250 |
| lē | 650 | 1500 |

Vowel [e] with tone [-]

| Word | F1 | F2 |
|---|---|---|
| tē | 550 | 2450 |
| tʰē | 550 | 2450 |
| cē | 525 | 2450 |
| kē | 550 | 2600 |
| bē | 525 | 2600 |
| dē | 500 | 2600 |
| fē | 525 | 2400 |
| vē | 525 | 2450 |
| sē | 500 | 2600 |
| zē | 500 | 2500 |
| xē | 500 | 2600 |
| gē | 500 | 2500 |
| mē | 500 | 2400 |
| nē | 500 | 2700 |
| ɲē | 500 | 2550 |
| ŋē | 500 | 2500 |
| hē | 500 | 2500 |
| lē | 500 | 2500 |

Vowel [ɛ] with tone [-]

| Word | F1 | F2 |
|---|---|---|
| tɛ̄ | 800 | 2450 |
| tʰɛ̄ | 750 | 2350 |
| cɛ̄ | 750 | 2300 |
| kɛ̄ | 750 | 2550 |
| bɛ̄ | 750 | 2600 |
| dɛ̄ | 700 | 2600 |
| fɛ̄ | 750 | 2400 |
| vɛ̄ | 700 | 2500 |
| sɛ̄ | 700 | 2500 |
| zɛ̄ | 750 | 2300 |
| xɛ̄ | 750 | 2550 |
| gɛ̄ | 700 | 2500 |
| mɛ̄ | 750 | 2650 |
| nɛ̄ | 700 | 2550 |
| ɲɛ̄ | 700 | 2550 |
| ŋɛ̄ | 700 | 2550 |
| hɛ̄ | 700 | 2500 |
| lɛ̄ | 700 | 2500 |

Vowel [ɔ] with tone [-]

| Word | F1 | F2 |
|---|---|---|
| tɔ̄ | 800 | 1050 |
| tʰɔ̄ | 750 | 1000 |
| cɔ̄ | 750 | 1100 |
| kɔ̄ | 800 | 1050 |
| bɔ̄ | 750 | 1000 |
| dɔ̄ | 850 | 1200 |
| fɔ̄ | 750 | 1000 |
| vɔ̄ | 750 | 1000 |
| sɔ̄ | 850 | 1200 |
| zɔ̄ | 850 | 1200 |
| xɔ̄ | 800 | 1150 |
| gɔ̄ | 800 | 1100 |
| mɔ̄ | 750 | 950 |
| nɔ̄ | 750 | 950 |
| ɲɔ̄ | 750 | 950 |
| ŋɔ̄ | 750 | 1000 |
| hɔ̄ | 800 | 1150 |
| lɔ̄ | 850 | 1200 |

Vowel [ɯ] with tone [-]

| Word | F1 | F2 |
|---|---|---|
| tɯ̄ | 300 | 1500 |
| tʰɯ̄ | 400 | 1450 |
| cɯ̄ | 400 | 1400 |
| kɯ̄ | 400 | 1450 |
| bɯ̄ | 400 | 1450 |
| dɯ̄ | 550 | 1500 |
| fɯ̄ | 400 | 1400 |
| vɯ̄ | 400 | 1350 |
| sɯ̄ | 550 | 1500 |
| zɯ̄ | 550 | 1650 |
| xɯ̄ | 400 | 1400 |
| gɯ̄ | 400 | 1500 |
| mɯ̄ | 400 | 1350 |
| nɯ̄ | 400 | 1650 |
| ɲɯ̄ | 400 | 1600 |
| ŋɯ̄ | 500 | 1400 |
| hɯ̄ | 350 | 1600 |
| lɯ̄ | 500 | 1600 |

Vowel [ʌ] with tone [-]

| Word | F1 | F2 |
|---|---|---|
| tʌ̄ | 750 | 1750 |
| tʰʌ̄ | 750 | 1800 |
| cʌ̄ | 750 | 1750 |
| kʌ̄ | 750 | 1750 |
| bʌ̄ | 850 | 1650 |
| dʌ̄ | 950 | 1700 |
| fʌ̄ | 850 | 1500 |
| vʌ̄ | 950 | 1550 |
| sʌ̄ | 700 | 1650 |
| zʌ̄ | 850 | 1800 |
| xʌ̄ | 950 | 1650 |
| gʌ̄ | 950 | 1800 |
| mʌ̄ | 800 | 1650 |
| nʌ̄ | 800 | 1850 |
| ɲʌ̄ | 700 | 1850 |
| ŋʌ̄ | 700 | 1850 |
| hʌ̄ | 800 | 1650 |
| lʌ̄ | 900 | 1600 |

Vowel [u] with tone [-]

| Word | F1 | F2 |
|---|---|---|
| tū | 400 | 850 |
| tʰū | 400 | 850 |
| cū | 400 | 825 |
| kū | 400 | 950 |
| bū | 400 | 850 |
| dū | 425 | 950 |
| fū | 400 | 850 |
| vū | 400 | 825 |
| sū | 425 | 800 |
| zū | 400 | 850 |
| xū | 400 | 900 |
| gū | 425 | 800 |
| mū | 400 | 1000 |
| nū | 425 | 850 |
| ɲū | 425 | 800 |
| ŋū | 400 | 1000 |
| hū | 400 | 850 |
| lū | 425 | 950 |

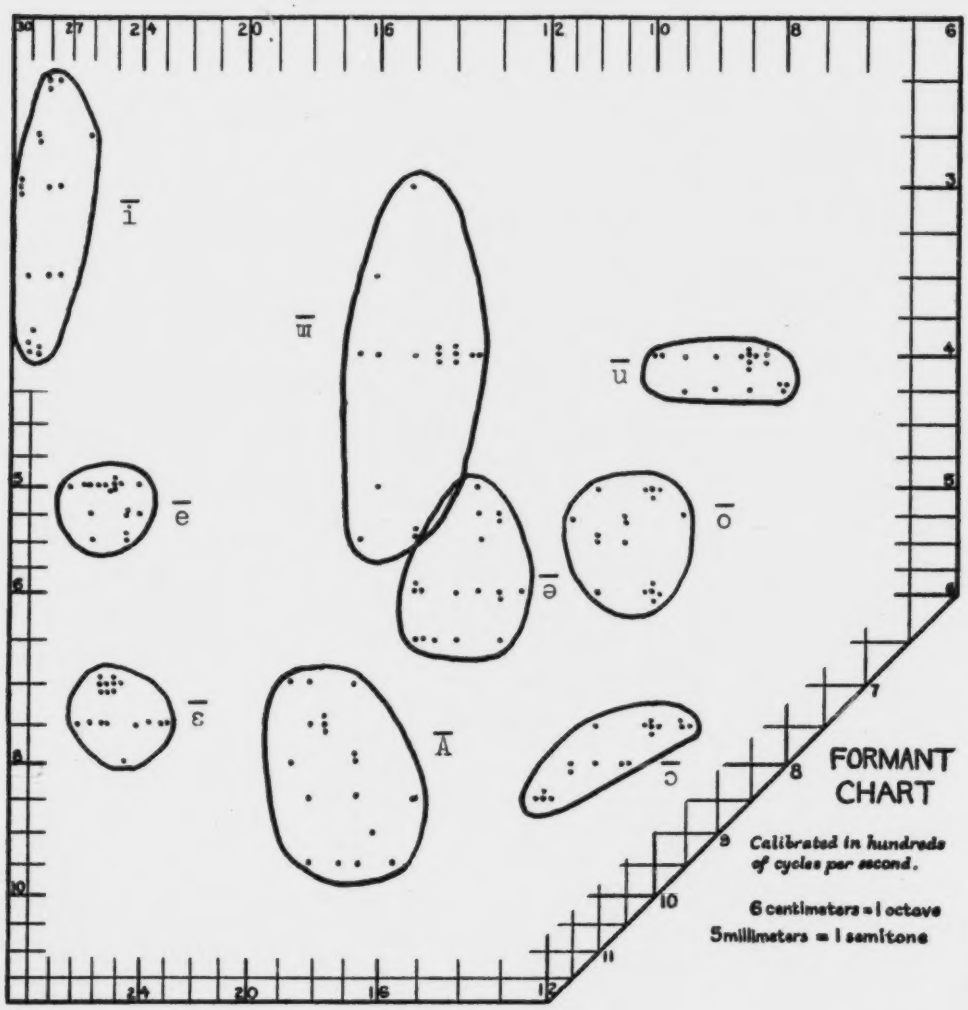
Vowel [o] with tone [-]

| Word | F1 | F2 |
|---|---|---|
| tō | 550 | 1100 |
| tʰō | 525 | 1050 |
| cō | 550 | 1100 |
| kō | 525 | 950 |
| bō | 600 | 1000 |
| dō | 600 | 1000 |
| fō | 600 | 1000 |
| vō | 600 | 1000 |
| sō | 600 | 1000 |
| zō | 550 | 1050 |
| xō | 525 | 1050 |
| gō | 525 | 1150 |
| mō | 500 | 1000 |
| nō | 500 | 1000 |
| ɲō | 500 | 1000 |
| ŋō | 500 | 1000 |
| hō | 500 | 1100 |
| lō | 600 | 1100 |

FIGURE 4

Simple vowels in open syllables

Level tone Informant 3



In looking at Figures 2, 3, and 4, one gets the impression that the vowel domains in these three figures show some difference. This is due to the previously mentioned characteristics of the formant bands of a female voice which make the identification of the center of formants very difficult. However, a careful comparison reveals that the relative positions of the vowel domains in each chart are comparable, and also that the vowels in the /t - n/ environment represented in Figure 2 seem to represent accurately the relative position of each vowel to the others. Figure 3 and Figure 4 may be regarded as extra data supporting 9 of the 11 vowel domains presented in Figure 2. In any event, the relative positions of /e/, /ə/, and /o/ which are of prime importance to this particular study are defined adequately. Therefore, the domains of /e/, /ə/, and /o/ as presented in Figures 1 and 2 will be used when comparing the phonetic qualities of simple vowels with the phonetic qualities of [ɜ], [ɪ], and [ɵ] in the following experiments.

Informant 1 had previously recorded syllables with the eleven simple vowels in the environment /t - n/ with level tone for a study of the inherent duration of vowels in Vietnamese. He left before we could make recordings of the complex nuclei in the same environment. However, from other recordings prepared by him, we selected some examples of syllables with complex nuclei in similar environments.

The measurements of Informant 1's simple vowels in the environment /t - n/ are reproduced in Table 5, and the graphic representation on a formant chart is seen in Figure 5.

Informant 2, also, had not recorded the desired material for this study before he left us. However, Informant 2's formant measurements were published in substantial amount in our Vol. IV and were useful as references in analysing his complex nuclei.

Spectrograms No. 1a - 11a show typical spectrograms of the simple vowels in the environment /t - n/ as spoken by Informant 4. The same vowels spoken by Informant 3, a female speaker, are shown in Spectrograms No. 1b - 11b. Typical spectrograms of the complex nuclei [Iɜ], [ɯɨ], and [Uθ] as spoken in the environment [t - n] are shown in Spectrograms No. 12a - b, 13a - b, and 14a - b, for Informants 4 and 3 respectively.

In the changing formants of the complex nuclei, there are no obvious points indicated at which the measurements should be taken. To determine the most reasonable points to be considered as the target or near target qualities of the complex nuclei, several steps were taken. Taking the complex nucleus [Iɜ], for example, first, the boundary between the two segments of the nucleus was identified with extreme care. Observation of steady states, upper formants, and amplitude contour, as shown in Spectrogram No. 15, served to identify the most logical point in time which could be considered as

TABLE 5

Formant measurements of
simple vowels in the environment /t - n/: Informant 1 cycles/second

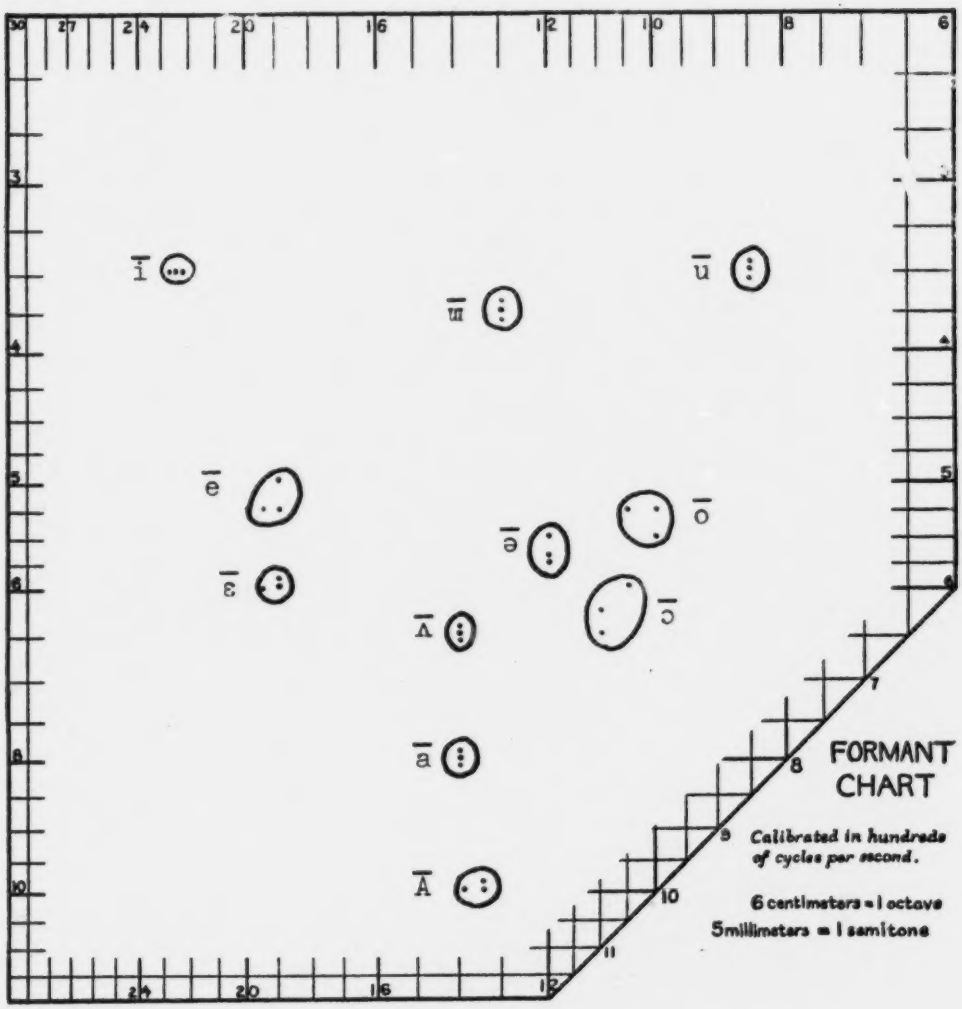
| | 1 | | 2 | | 3 | | 4 | |
|---|---|---|---|---|---|---|---|---|
| Word | F1 | F2 | F1 | F2 | F1 | F2 | F1 | F2 |
| tīn | | | 350 | 2250 | 350 | 2250 | 350 | 2250 |
| tēn | | | 525 | 1900 | 500 | 1900 | 525 | 1950 |
| tɛn | | | 600 | 1900 | 600 | 1900 | 600 | 1950 |
| tān | | | 800 | 1400 | 800 | 1400 | 800 | 1400 |
| tĀn | | | 1000 | 1350 | 1000 | 1350 | 1000 | 1400 |
| tʌn | | | 650 | 1400 | 650 | 1400 | 650 | 1400 |
| tən | | | 575 | 1200 | 575 | 1200 | 550 | 1200 |
| tɯn | | | 375 | 1300 | 375 | 1300 | 375 | 1300 |
| tōn | | | 600 | 1050 | 650 | 1100 | 625 | 1100 |
| tōn | | | 525 | 1050 | 550 | 1000 | 525 | 1000 |
| tūn | | | 350 | 850 | 350 | 850 | 350 | 850 |

Blank spaces indicate where precise measurements were not obtainable.

FIGURE 5

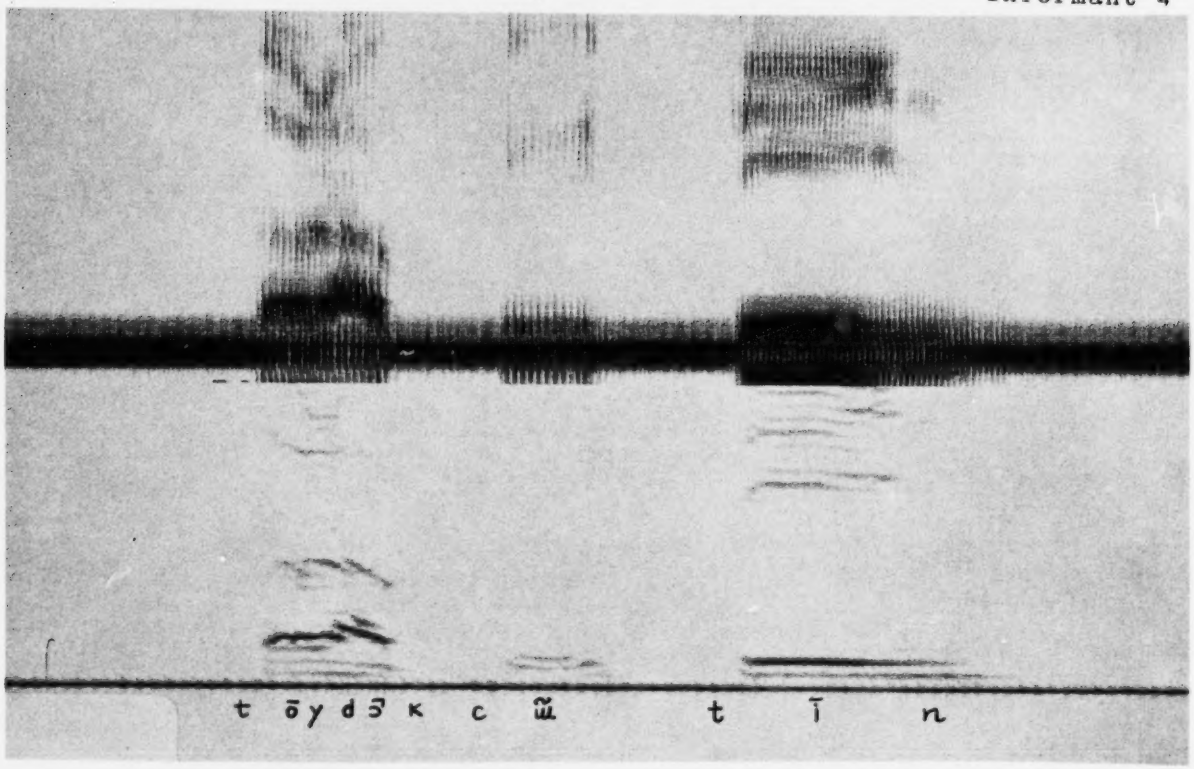
Simple vowels in the environment /t - n/

Level tone Informant 1

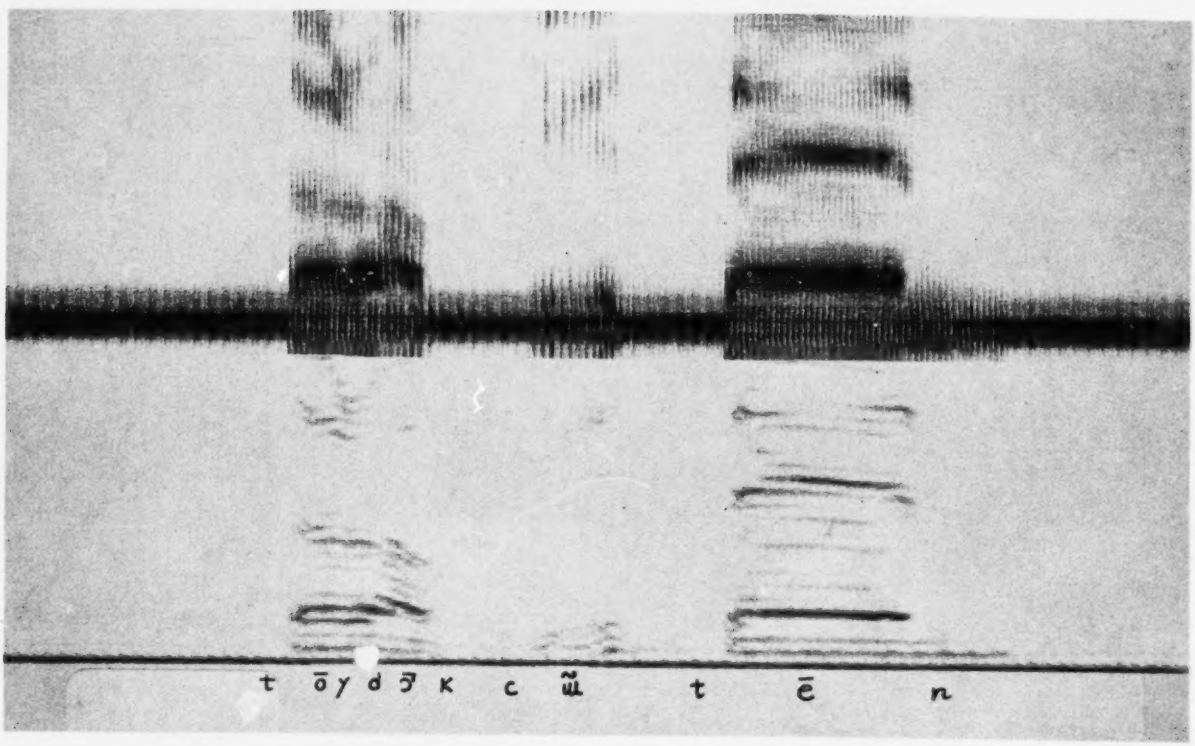


SPECTROGRAM NO. 1a

Informant 4

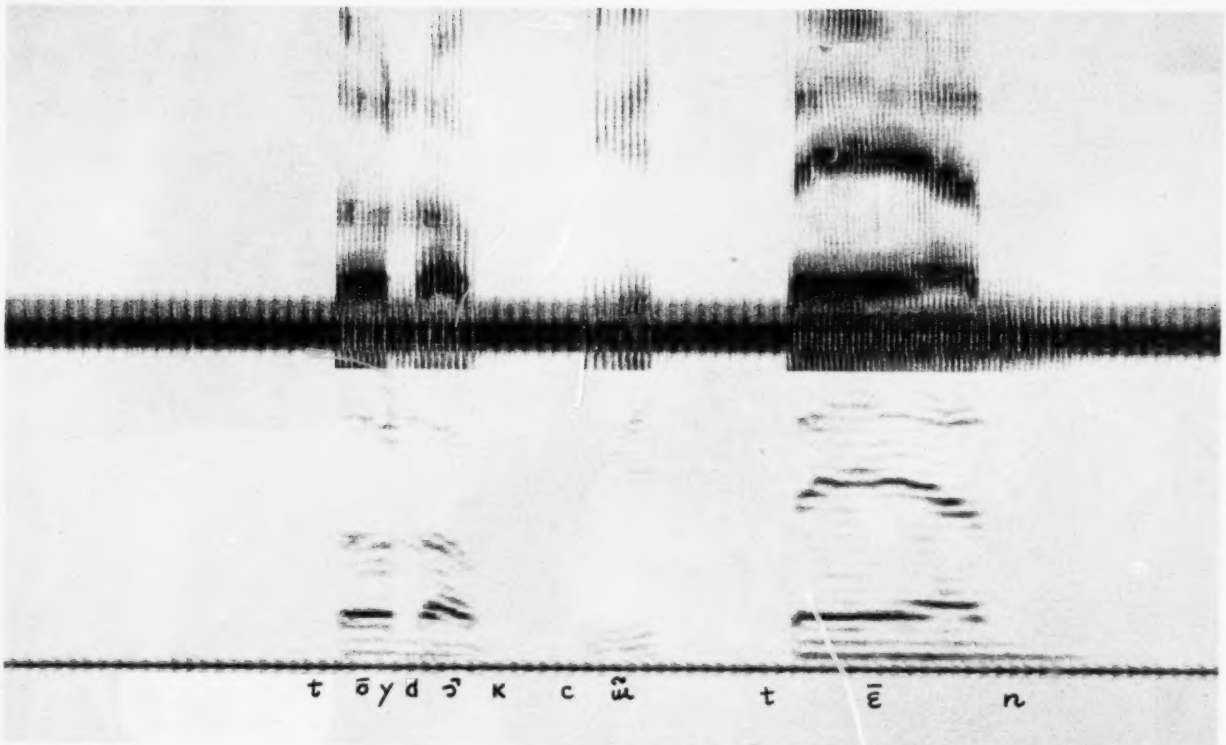



SPECTROGRAM NO. 2a

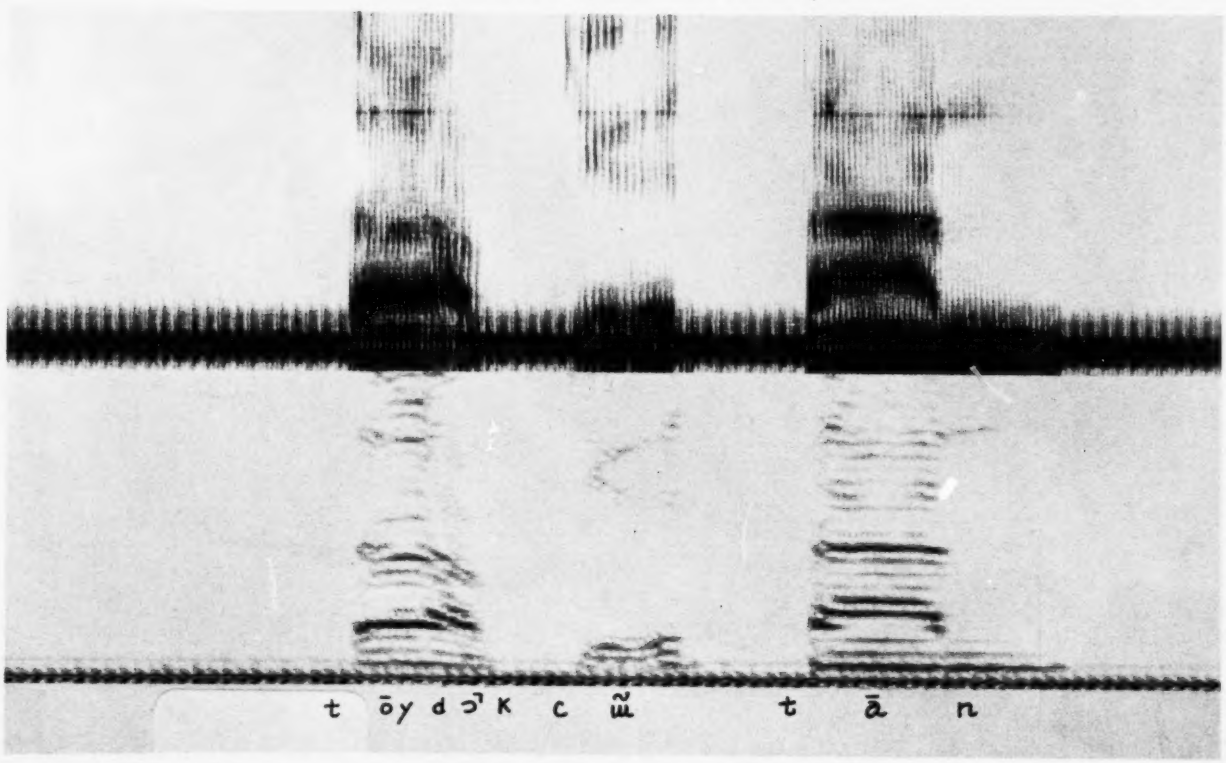


SPECTROGRAM NO. 3a

Informant 4

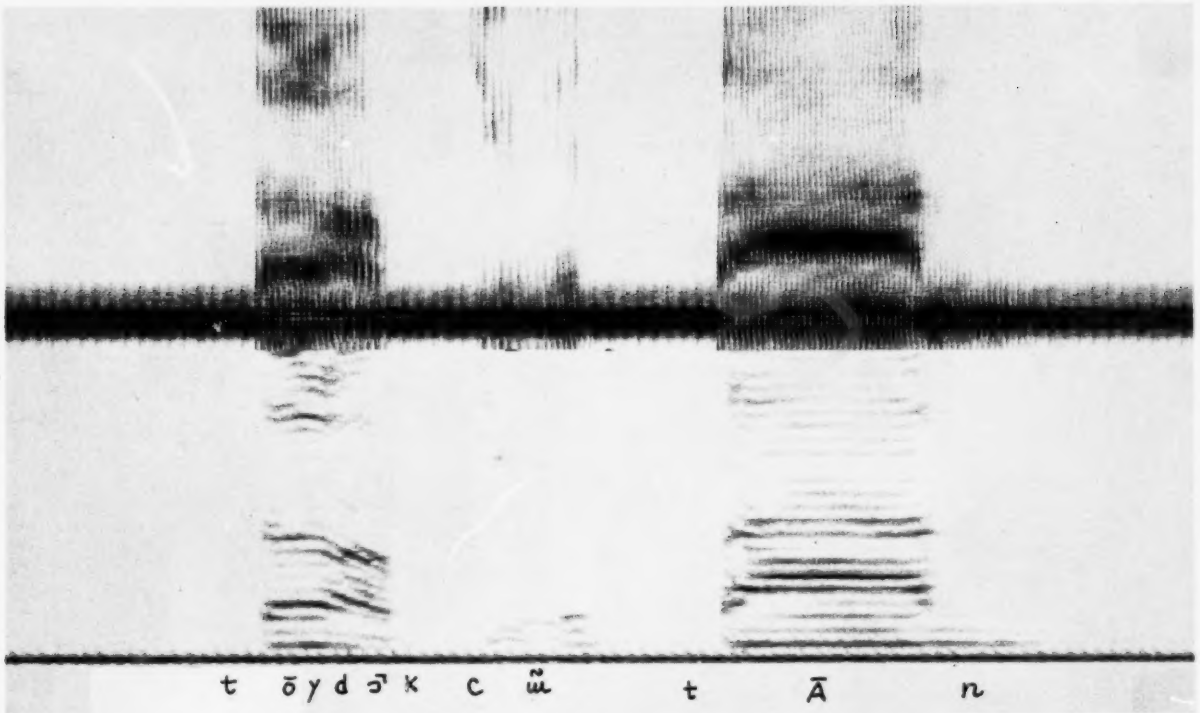



SPECTROGRAM NO. 4a

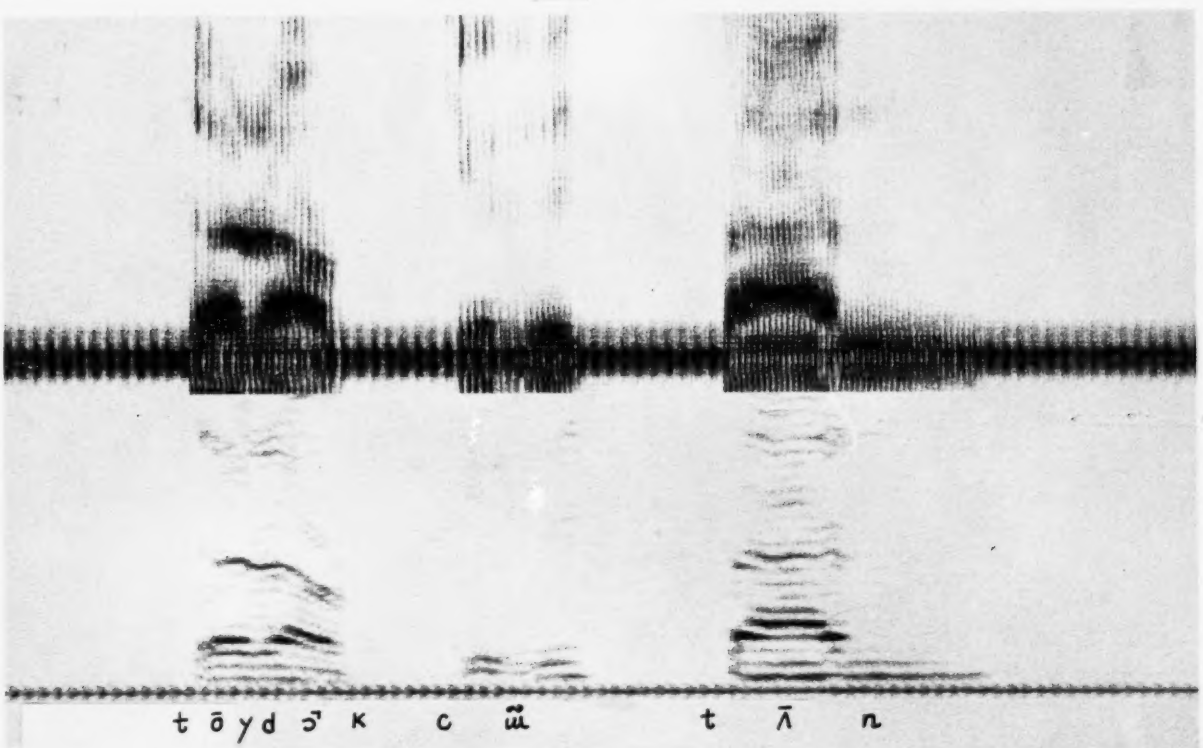


SPECTROGRAM NO. 5a

Informant 4

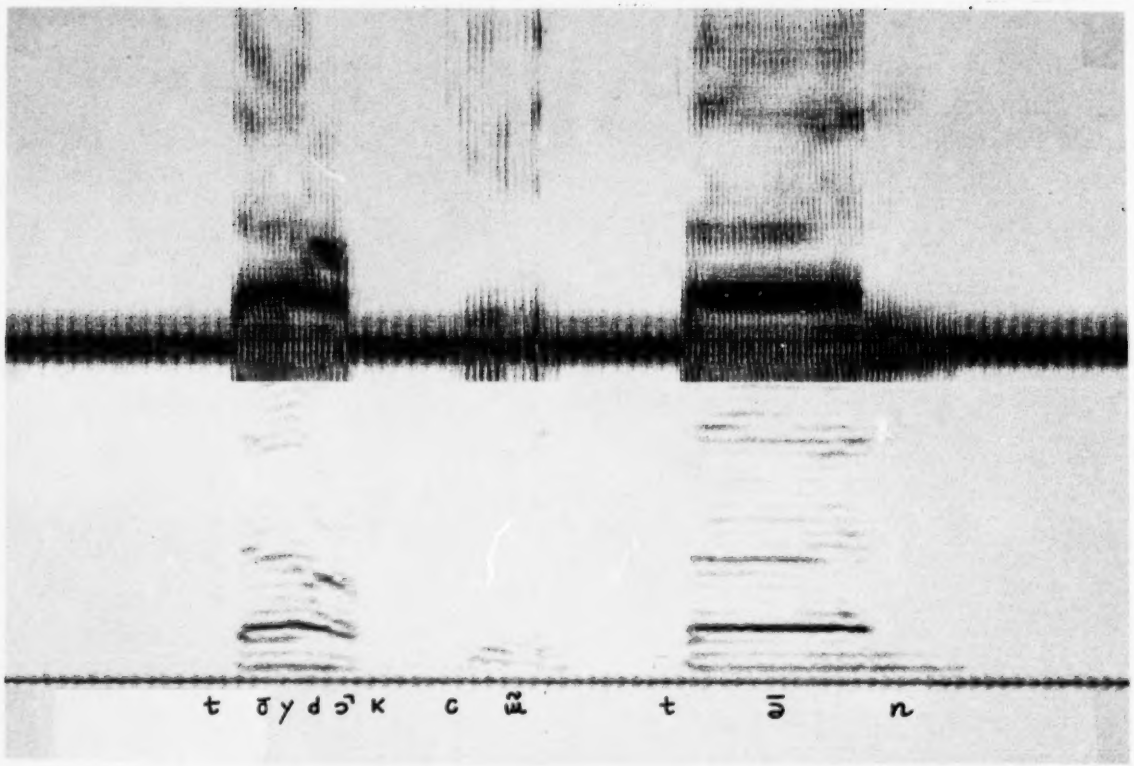



SPECTROGRAM NO. 6a

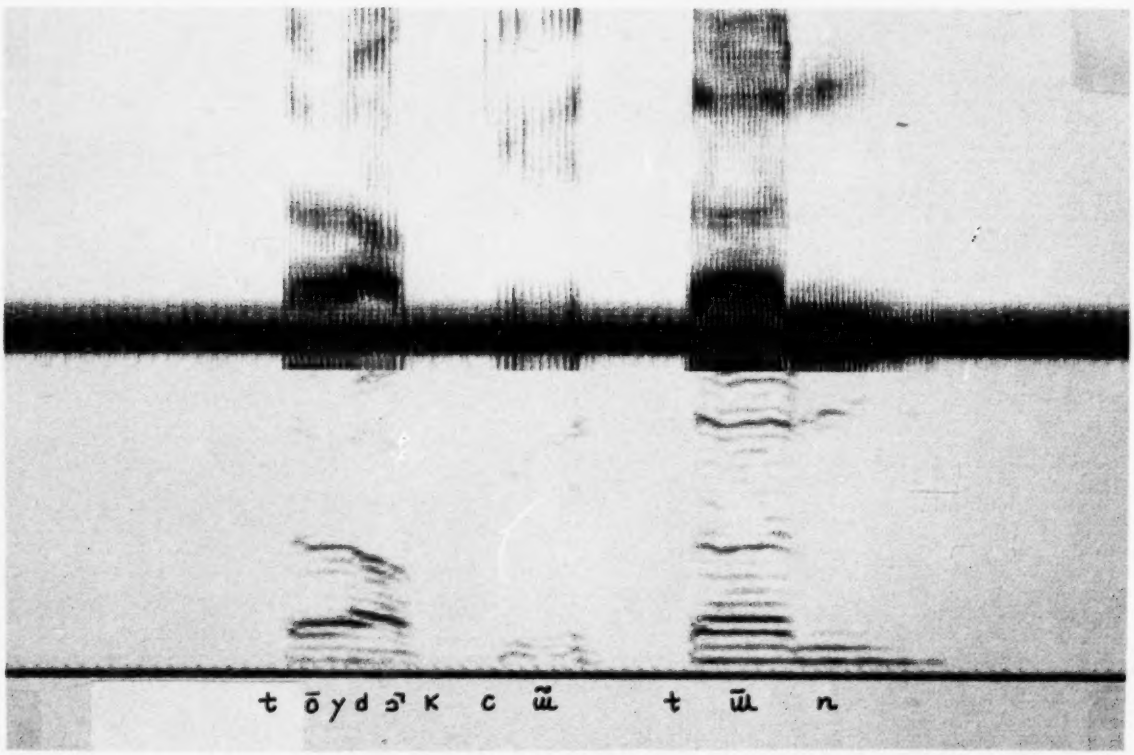


SPECTROGRAM NO. 7a

Informant 4

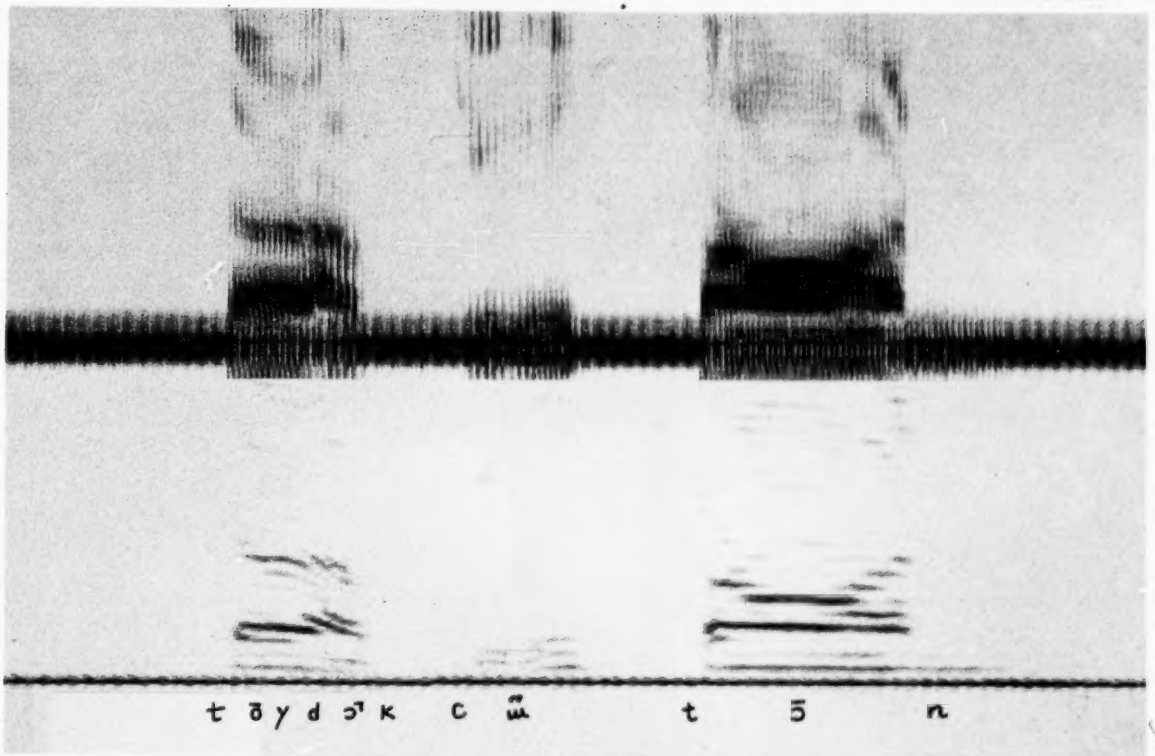



SPECTROGRAM NO. 8a

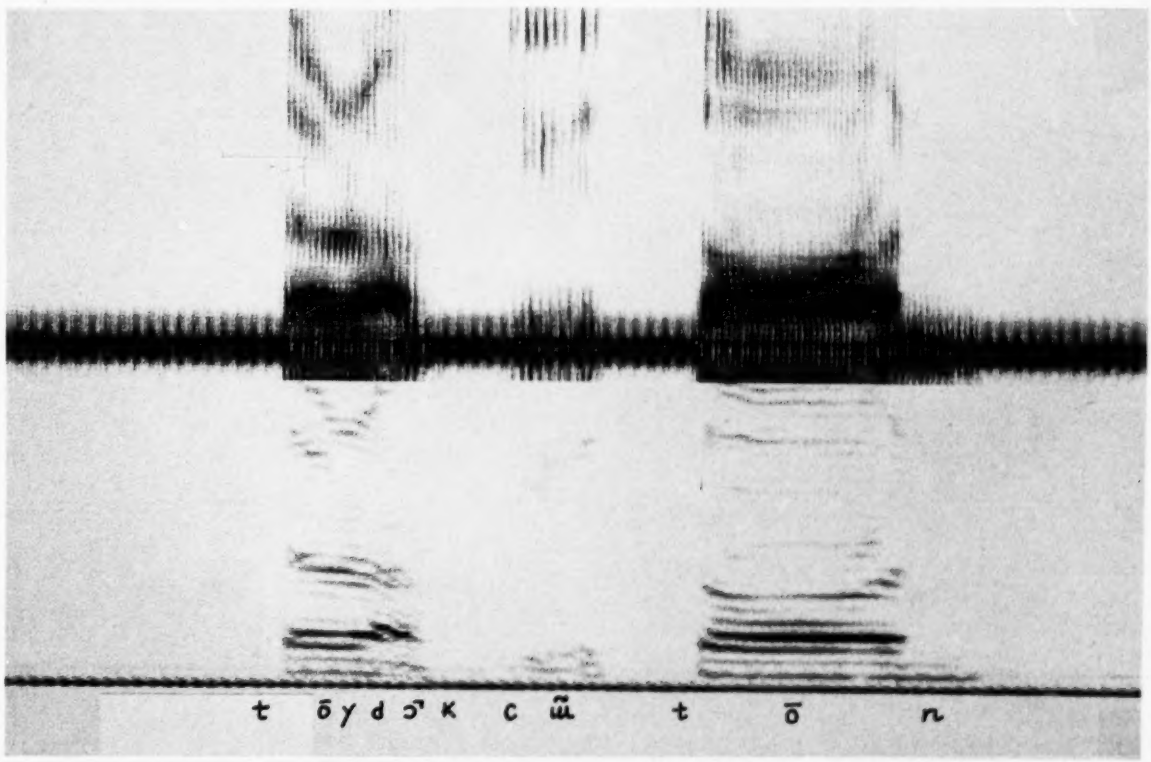


SPECTROGRAM NO. 9a

Informant 4

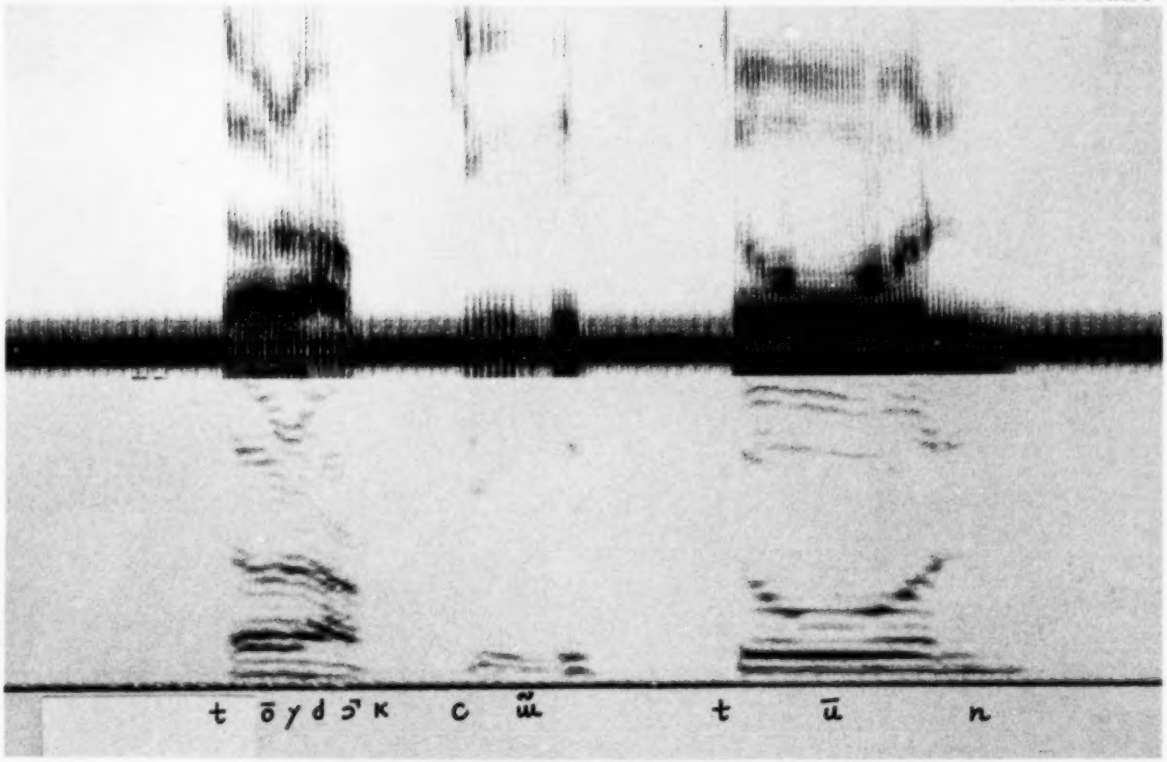



SPECTROGRAM NO. 10a



SPECTROGRAM NO. 11a

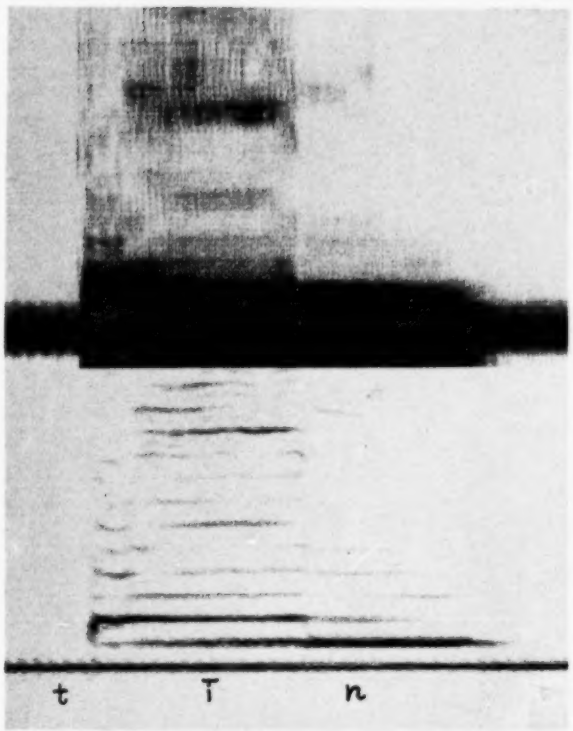
Informant 4

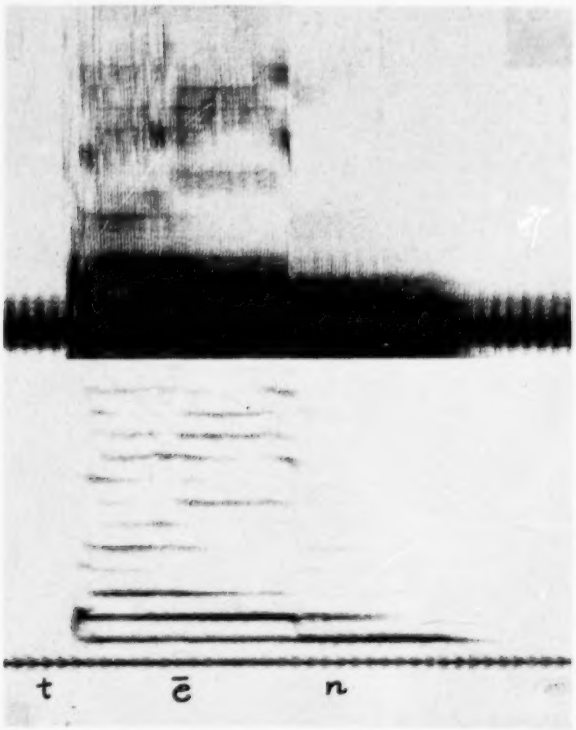


SPECTROGRAM NO. 1b

SPECTROGRAM NO. 2b

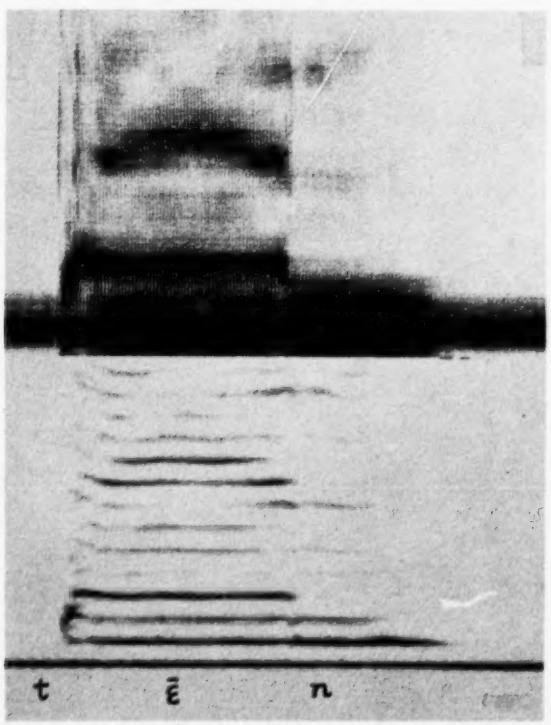
Informant 3

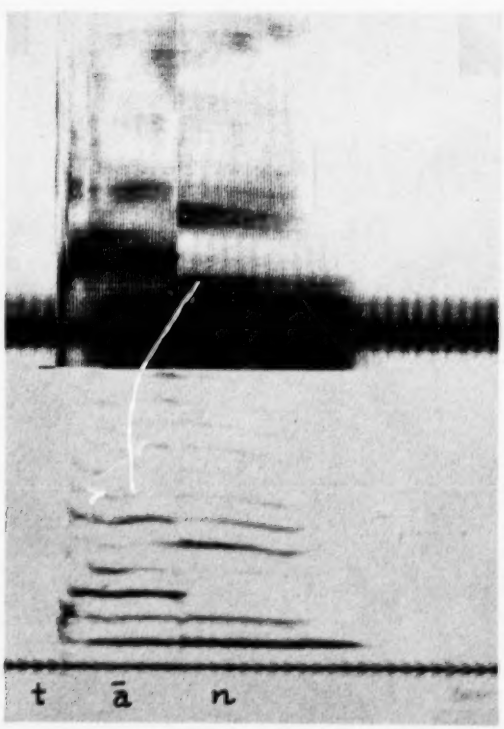



SPECTROGRAM NO. 3b

SPECTROGRAM NO. 4b

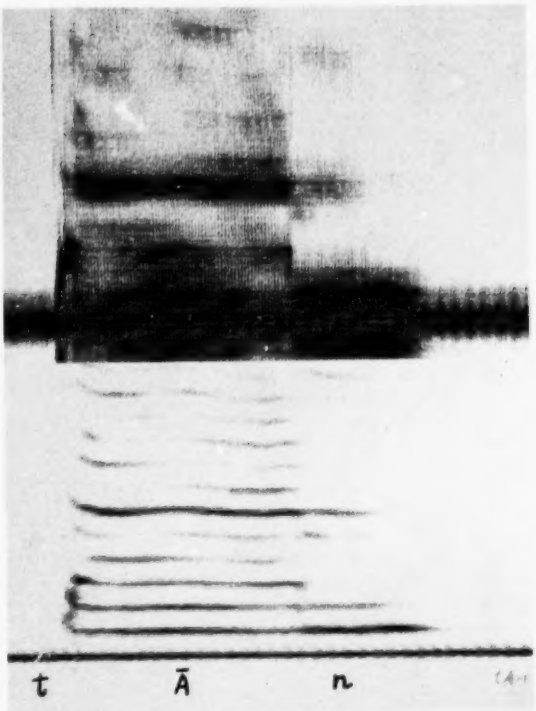


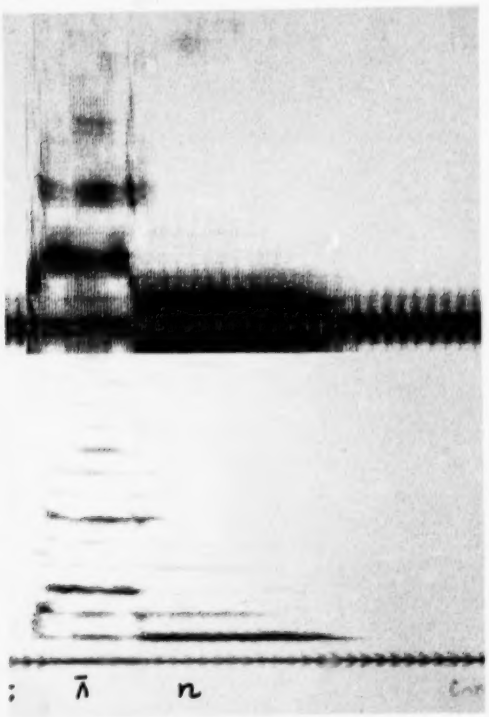



SPECTROGRAM NO. 5b

SPECTROGRAM NO. 6b

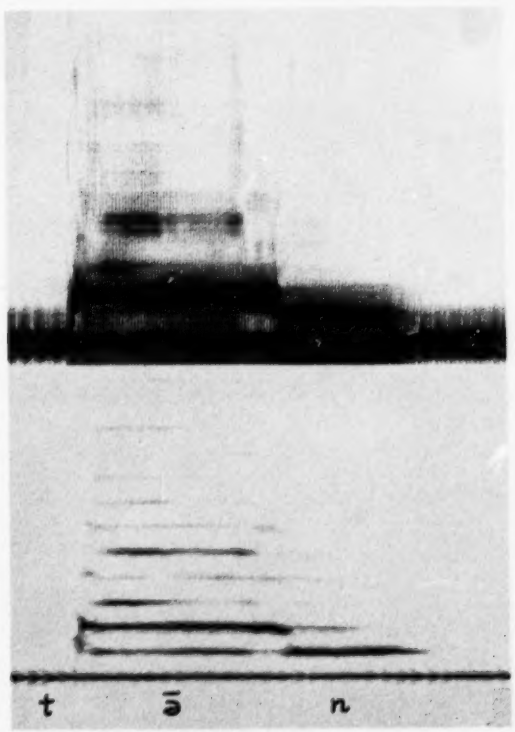
Informant 3

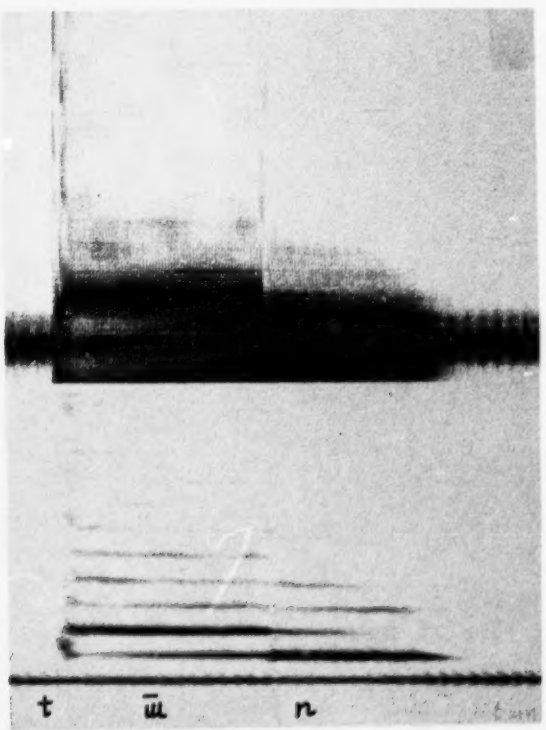



SPECTROGRAM NO. 7b

SPECTROGRAM NO. 8b

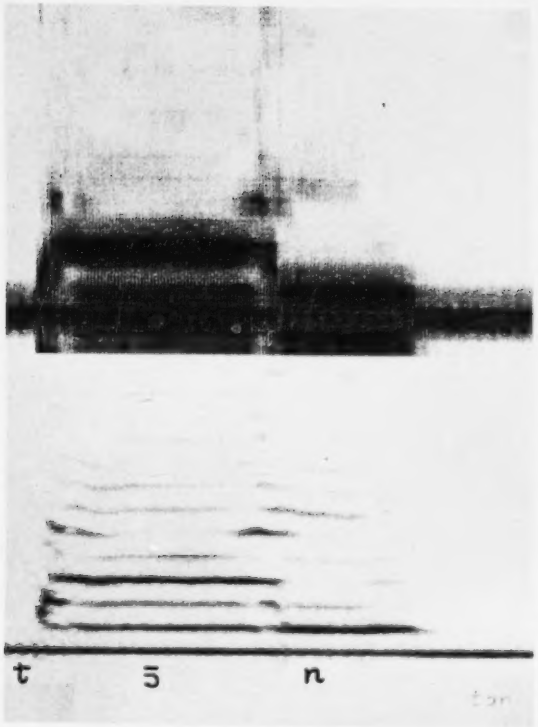


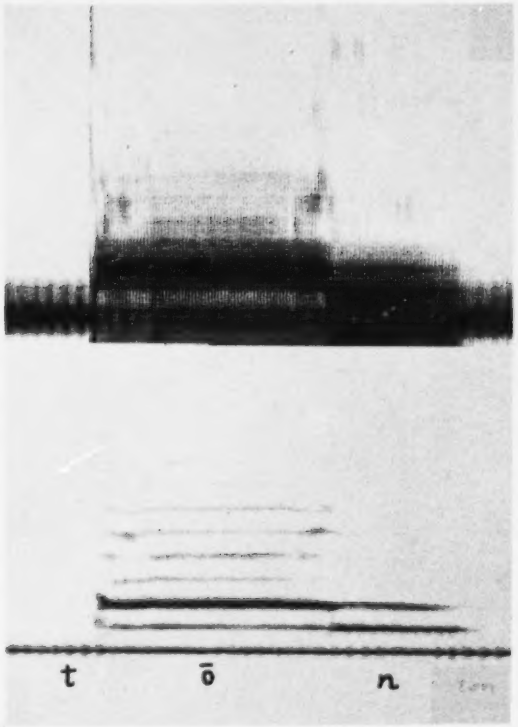



SPECTROGRAM NO. 9b

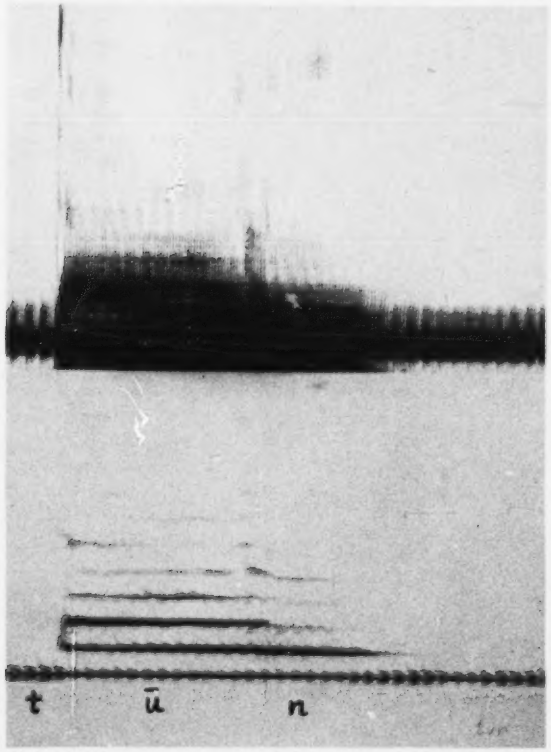
SPECTROGRAM NO. 10b

Informant 3

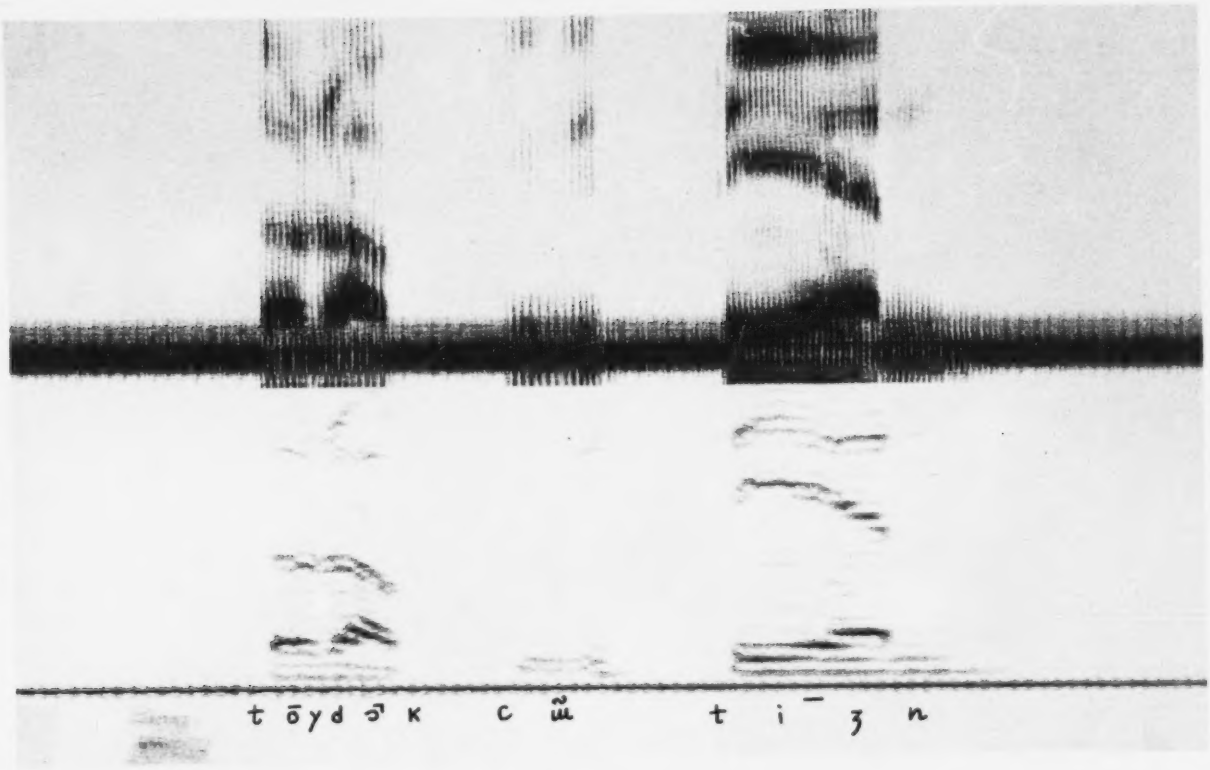


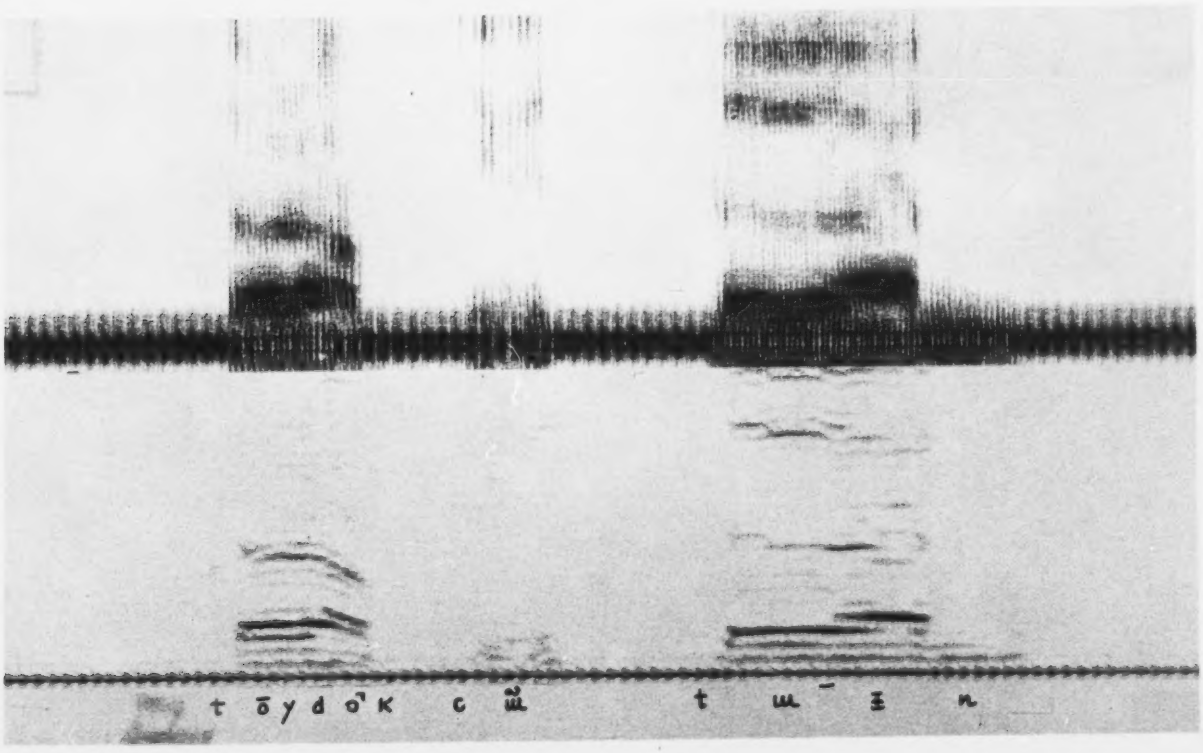

SPECTROGRAM NO. 11b



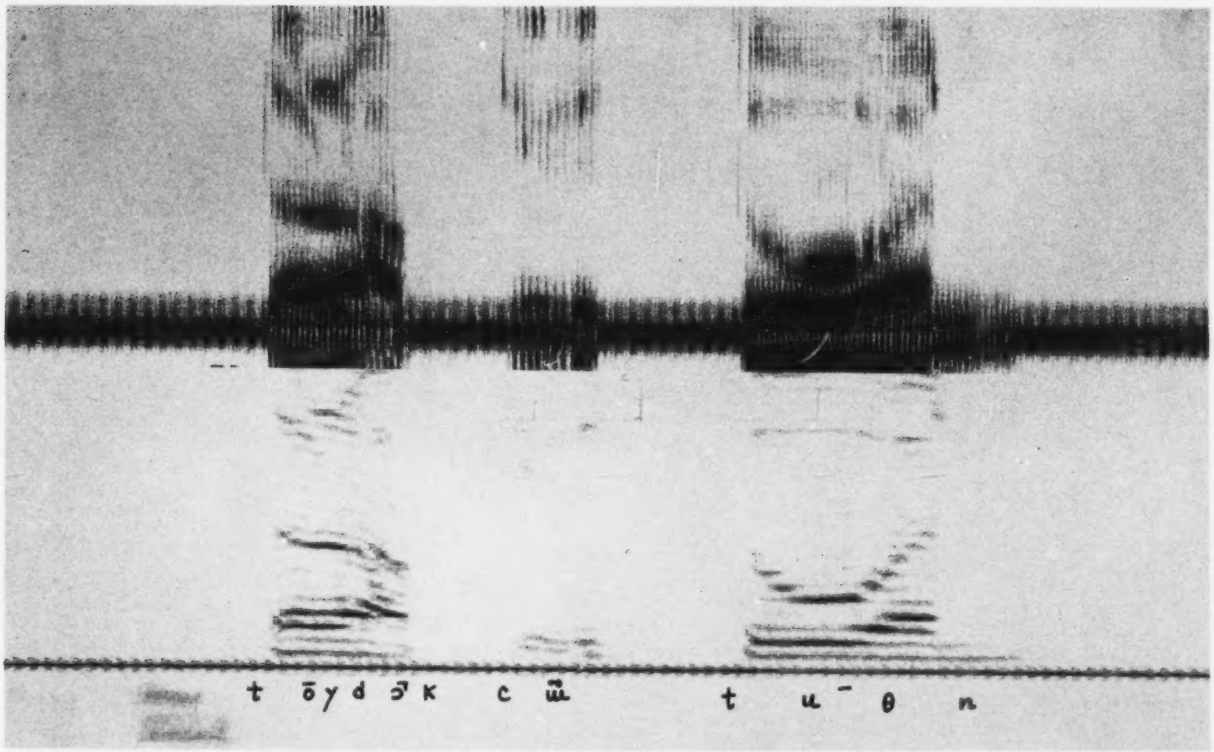
SPECTROGRAM NO. 12a Informant 4




SPECTROGRAM NO. 13a

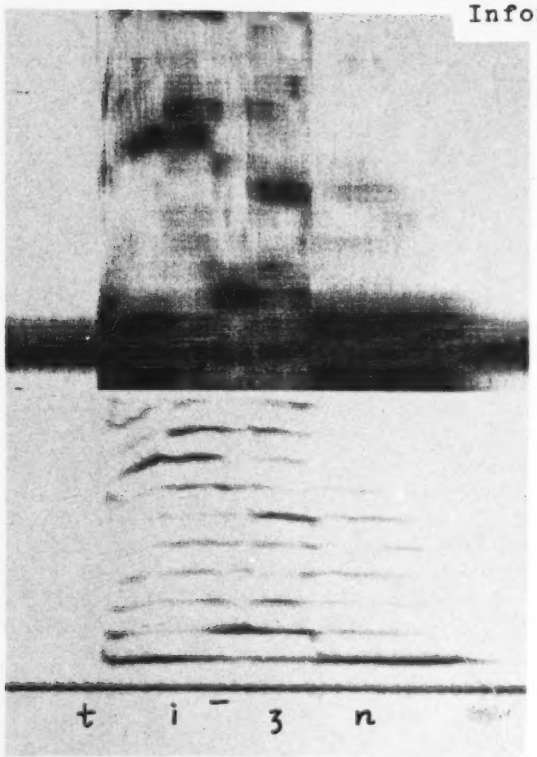


SPECTROGRAM NO. 14a Informant 4

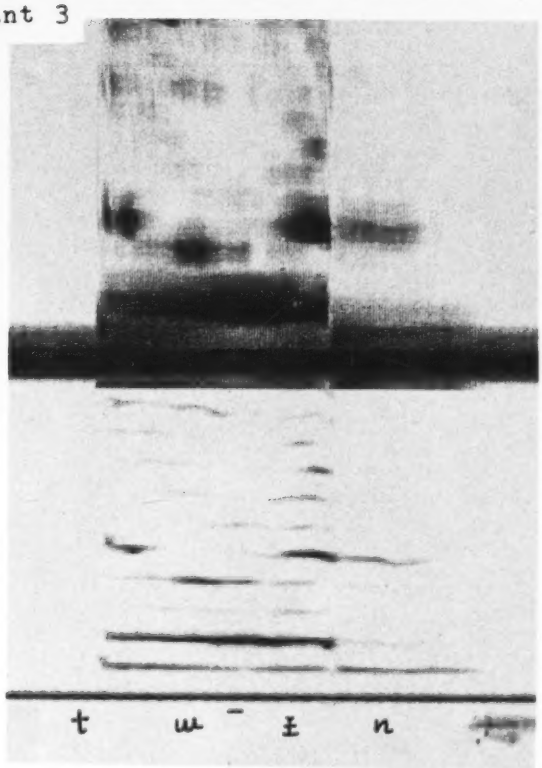


SPECTROGRAM NO. 12b

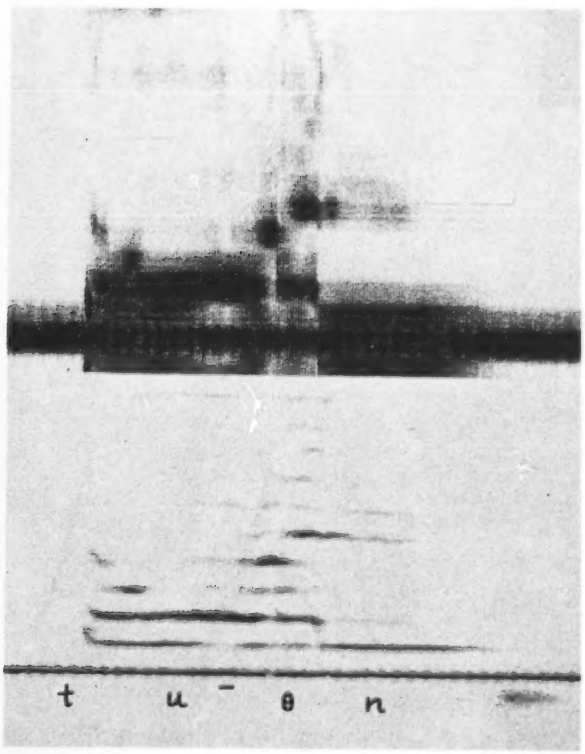
Informant 3




SPECTROGRAM NO. 13b




SPECTROGRAM NO. 14b



a boundary between the 2 segments. The mid-way point between the beginning of the formant and this boundary was then taken as the target quality of the first segment of the nucleus, [I]; and, the mid-way point between the boundary and the end of the formant was considered as the target of the second segment, [ɜ].

Recordings of [Iɜ], [ɯɨ], and [Uθ] in the environment /t - n/ were made using the same frame sentence /to͞y dɔ͞k cɯ̃ t͞-n; t͞-n, t͞-n, t͞-n./

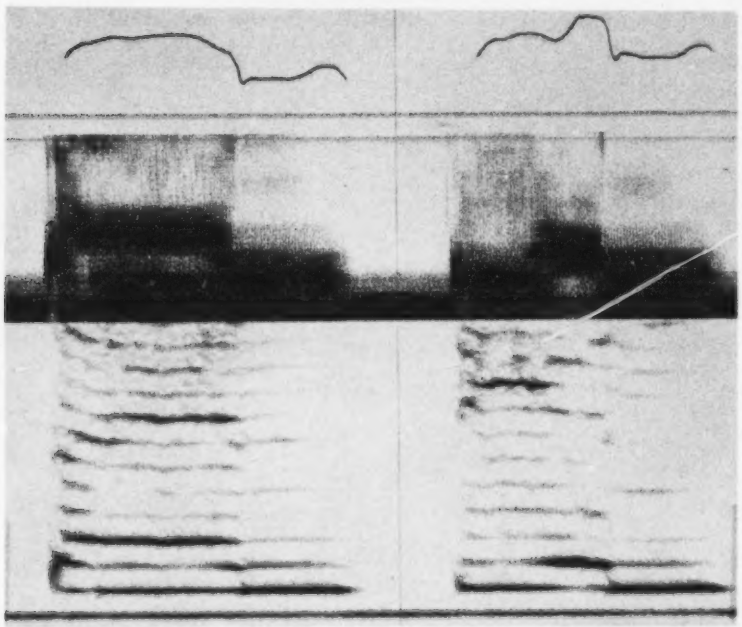
Informant 4's speech was examined first because it is easier to work with the formant measurements of a male voice. On listening carefully to the initial vowel qualities of the complex nuclei, it was found that they sound very much like /i/, /ɯ/, and /u/ respectively. To confirm this auditory impression with acoustic data, we measured F1 and F2 of [I] and [ɜ] in the word [tI͞ɜ͞n], of [ɯ] and [ɨ] in the word [tɯ͞ɨ͞n] and of [U] and [θ] in the word [tUθn]. These measurements are presented in Table 6.

Figure 6 is a composite graphic representation of the domains of the complex nuclei [Iɜ], [ɯɨ], [Uθ] and the domains of the simple vowels. The dots and the solid line circles represent the measurements of Table 6, while the broken line circles represent the domains of the simple vowels of the same speaker as obtained earlier and recorded in Table 1 and Figure 1.

SPECTROGRAM NO. 15

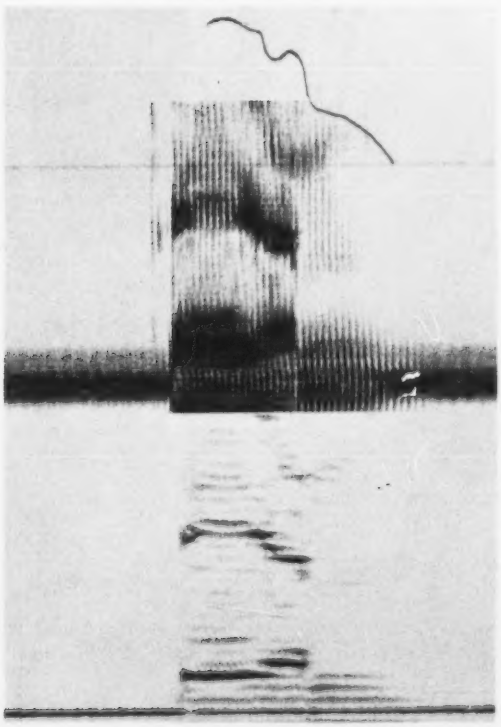
Amplitude contours of [ɛ] and [iʒ]

Informant 3



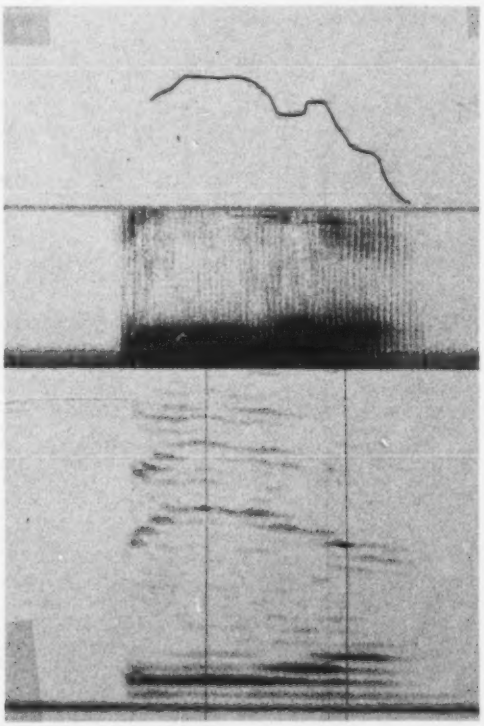
t ɛ n t i ʒ n

Informant 1



t i ʒ n

Informant 4



t i ʒ

TABLE 6

Formant measurements of complex nuclei in the environment /t - n/: Informant 4 cycles/second

Segment [i] with tone [-]

| Word | 1 F1 F2 F3 | 2 F1 F2 F3 | 3 F1 F2 F3 | 4 F1 F2 F3 |
|---|---|---|---|---|
| tī3n | 300 2300 2950 | 300 2200 2950 | 350 2250 2900 | 350 2150 2950 |
| | 300 2350 2850 | 300 2300 3050 | 350 2250 2800 | 350 2200 2800 |
| | 300 2300 2850 | 300 2300 3000 | 300 2250 3000 | 350 2100 2900 |
| | 300 2300 2800 | 300 2300 3000 | 300 2250 2950 | 300 2400 2950 |
| | 300 2350 2950 | 300 2350 3000 | 300 2250 2900 | 300 2400 3000 |

Segment [ɜ] with tone [-]

| Word | 1 F1 F2 F3 | 2 F1 F2 F3 | 3 F1 F2 F3 | 4 F1 F2 F3 |
|---|---|---|---|---|
| tī3n | 600 1950 2800 | 600 1950 2850 | 550 1950 2800 | 550 2000 2800 |
| | 550 2000 2800 | 550 2050 2850 | 575 1950 2800 | 550 2000 2800 |
| | 625 2000 2800 | 625 2000 2850 | 600 1950 2850 | 600 1900 2800 |
| | 600 1950 2750 | 600 1950 2750 | 600 2000 2800 | 600 2000 2850 |
| | 650 2000 2950 | 650 2000 2800 | 650 2000 2850 | 650 2000 2800 |

Segment [ɯ] with tone [-]

| Word | 1 F1 F2 F3 | 2 F1 F2 F3 | 3 F1 F2 F3 | 4 F1 F2 F3 |
|---|---|---|---|---|
| tɯ̄n | 450 1450 | 450 1400 | 450 1400 | 450 1400 |
| | 450 1400 | 450 1450 | 425 1350 | 450 1400 |
| | 450 1450 | 450 1350 | 450 1350 | 500 1400 |
| | 400 1350 | 450 1450 | 450 1400 | 400 1450 |
| | 450 1450 | 500 1500 | 450 1350 | 500 1300 |

Segment [ɨ] with tone [-]

| Word | 1 F1 F2 F3 | 2 F1 F2 F3 | 3 F1 F2 F3 | 4 F1 F2 F3 |
|---|---|---|---|---|
| tɨ̄n | 550 1500 | 550 1450 | 550 1450 | 600 1450 |
| | 600 1400 | 600 1400 | 600 1400 | 600 1400 |
| | 600 1400 | 600 1450 | 600 1400 | 600 1400 |
| | 650 1450 | 625 1450 | 600 1450 | 600 1450 |
| | 650 1450 | 600 1400 | 625 1450 | 650 1450 |

Segment [u] with tone [-]

| Word | 1 F1 F2 F3 | 2 F1 F2 F3 | 3 F1 F2 F3 | 4 F1 F2 F3 |
|---|---|---|---|---|
| tū3n | 300 800 | 300 800 | 300 800 | 350 750 |
| | 325 750 | 325 800 | 350 750 | 325 750 |
| | 300 800 | 350 800 | 350 800 | 400 800 |
| | 350 800 | 400 850 | 350 850 | 350 800 |
| | 300 800 | 350 800 | 400 800 | 300 800 |

Segment [ɵ] with tone [-]

| Word | 1 F1 F2 F3 | 2 F1 F2 F3 | 3 F1 F2 F3 | 4 F1 F2 F3 |
|---|---|---|---|---|
| tɵ̄n | 550 1150 | 550 1250 | 500 1100 | 500 1100 |
| | 500 1100 | 500 1050 | 500 1100 | 500 1050 |
| | 550 1100 | 550 1100 | 550 1200 | 550 1150 |
| | 550 1150 | 550 1150 | 500 1100 | 550 1150 |
| | 550 1200 | 550 1100 | 550 1150 | 550 1100 |

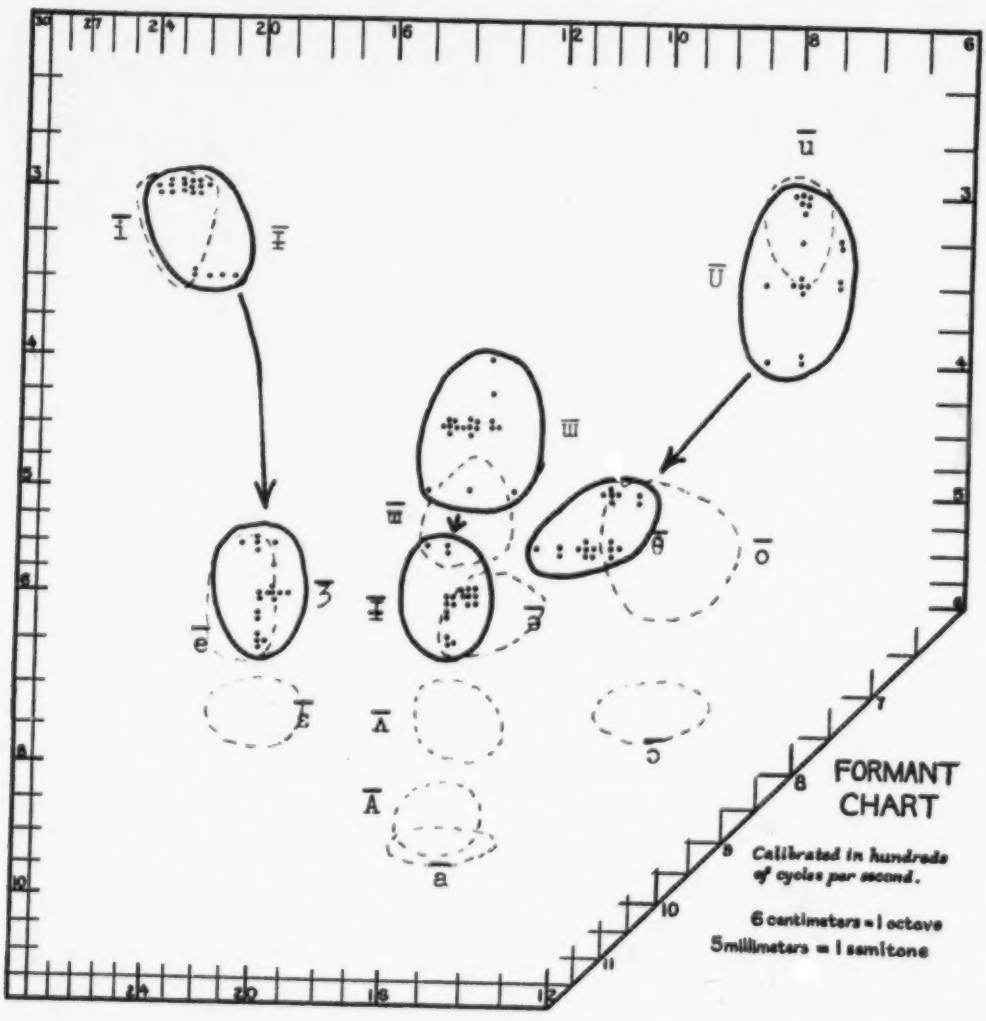
Blank spaces indicate where precise measurements were not obtainable.

FIGURE 6

Complex nuclei compared with simple vowels in the environment /t - n/

Level tone

Informant 4



As can be seen in Figure 6, the first segments of the complex nuclei [I͡ɜ], [ɯ̲͡ɪ̈], and [U͡θ] are phonetically similar to [i], [ɯ], and [u]. The acoustic data confirms the auditory impression shared by all analysts that the first segments of the complex nuclei [I͡ɜ], [ɯ͡ɪ̈], and [U͡θ] are phonetically the same as [i], [ɯ], and [u] respectively. They are so phonetically similar, in fact, that we will hereafter transcribe them as [i], [ɯ], and [u] in our data.

In Figure 6, it is clearly observed that the formant measurements of [ɜ], [ɪ̈], and [θ] form three distinct areas. The domain of [ɜ] corresponds closely to that of /e/, [ɪ̈] corresponds roughly to that of /ə/, and the domain of [θ] is closer to that of /o/ than to any other vowel.

Having confirmed that the qualities of [I ɯ U] are the same as /i ɯ u/ of the simple vowels, we then focused our attention on the second elements only, in the formant analysis of the other informants. Using the same procedures,we measured F1 and F2 of [ɜ], [ɪ̈], and [θ] as spoken by Informant 3.

Table 7 represents F1 and F2 of [ɜ], [ɪ̈], and [θ] in [t$\overline{\text{iɜ}}$n], [t$\overline{\text{ɯɪ̈}}$n], and [t$\overline{\text{uθ}}$n] as spoken by Informant 3. Figure 7 is the corresponding composite graphic representation of the domains of the second segment of the complex nuclei and the domains of the simple vowels. Solid lines circle the domains of [ɜ], [ɪ̈], and [θ] as presented in Table 7, while broken lines circle the simple vowel qualities presented in Table 2 and Figure 2.

In Figure 7 the analysis of [ɝ], [ɨ], and [θ] as being three phonetically different sounds is further supported. In Informant 3's speech, also, the domain of [ɝ] overlaps with /e/, [ɨ] overlaps with /ə/, and [θ] overlaps with /o/. Since /e/, /ə/, and /o/ are three distinct phonemes, it is reasonable to consider [ɝ], [ɨ], and [θ] as three different vocalic qualities of 3 different vowels rather than as a single phoneme, such as /ə/, with three allophones. The reason some English speakers hear all three sounds as /ə/ may be attributed to the linguistic habit of the native speakers of English to classify a rather wide range of mid-central vowel sounds as the phoneme /ə/.

Informant 1 had made a few recordings of complex nuclei before leaving us. In the limited amount of data available, we found a recording of the words, [tɪ͡ɝn], [tʊ̄͡ɨn], and [tʊ̄͡θn] spoken in our standard frame sentence. Spectrograms and measurements were made as presented in Table 8. Using the same techniques as those used in the experiments with Informants 4 and 3, the figures were converted into the graphic representation shown in Figure 8. Although no conclusion can be drawn from such small statistical data as that of Informant 1, it also seems to support the analysis of /ɝ/, /ɨ/, and /θ/ as three different sounds rather than one.

Through the acoustic phonetic analysis of the complex nuclei [Iɝ], [ʊɨ], and [Uθ] in the environment /t - n/, we

TABLE 7

Formant measurements of
second segments of the complex nuclei in the environment /t - n/: Informant 3
cycles/second

Segment [ɨ] with tone [-]

| Word | 1 F1 | F2 | F3 | 2 F1 | F2 | F3 | 3 F1 | F2 | F3 | 4 F1 | F2 | F3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| tɨ̄n | 600 | 1850 | | 600 | 1900 | | 600 | 1850 | | 600 | 1850 | |
| | 625 | 1850 | | 575 | 1800 | | 600 | 1850 | | 600 | 1900 | |
| | 600 | 1850 | | 600 | 1850 | | 600 | 1800 | | 600 | 1950 | |
| | 600 | 2000 | | 600 | 2100 | | 600 | 1850 | | 600 | 1950 | |
| | 575 | 2050 | | 550 | 2000 | | 600 | 1950 | | 600 | 2100 | |
| | 625 | 1950 | | 650 | 1950 | | 600 | 1900 | | 600 | 1900 | |
| | 600 | 1900 | | 600 | 1900 | | 600 | 1850 | | 600 | 1850 | |
| | 600 | 1900 | | 600 | 1850 | | 600 | 1850 | | 600 | 1850 | |
| | 600 | 1850 | | 600 | 1850 | | 600 | 1850 | | 600 | 1850 | |
| | 600 | 2000 | | 600 | 1900 | | 600 | 1850 | | 625 | 1900 | |

Segment [ɨ̞] with tone [-]

| Word | 1 F1 | F2 | F3 | 2 F1 | F2 | F3 | 3 F1 | F2 | F3 | 4 F1 | F2 | F3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| tɨ̞̄n | 600 | 1550 | | 600 | 1550 | | 600 | 1550 | | 600 | 1550 | |
| | 600 | 1550 | | 600 | 1550 | | 600 | 1550 | | 600 | 1550 | |
| | 600 | 1550 | | 600 | 1550 | | 625 | 1500 | | 600 | 1550 | |
| | 600 | 1550 | | 550 | 1500 | | 575 | 1500 | | 600 | 1500 | |
| | 600 | 1570 | | 575 | 1500 | | 600 | 1550 | | 600 | 1500 | |
| | 625 | 1500 | | 650 | 1600 | | 600 | 1600 | | 625 | 1600 | |
| | 625 | 1600 | | 625 | 1450 | | 600 | 1550 | | 600 | 1550 | |
| | 650 | 1600 | | 600 | 1400 | | 625 | 1550 | | 600 | 1550 | |
| | 650 | 1600 | | 600 | 1600 | | 600 | 1550 | | 600 | 1550 | |
| | 550 | 1500 | | 600 | 1550 | | 600 | 1550 | | 600 | 1550 | |

Segment [ɵ] with tone [-]

| Word | 1 F1 | F2 | F3 | 2 F1 | F2 | F3 | 3 F1 | F2 | F3 | 4 F1 | F2 | F3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| tɵ̄n | 600 | 1250 | | 600 | 1250 | | 600 | 1250 | | 600 | 1250 | |
| | 600 | 1250 | | 600 | 1250 | | 600 | 1250 | | 600 | 1250 | |
| | 600 | 1250 | | 600 | 1250 | | 600 | 1200 | | 575 | 1200 | |
| | 600 | 1350 | | 600 | 1200 | | 550 | 1200 | | 600 | 1200 | |
| | 600 | 1250 | | 575 | 1200 | | 575 | 1300 | | 550 | 1200 | |
| | 600 | 1300 | | 600 | 1300 | | 600 | 1250 | | 600 | 1300 | |
| | 625 | 1300 | | 625 | 1300 | | 625 | 1300 | | 600 | 1300 | |
| | 600 | 1300 | | 600 | 1300 | | 600 | 1300 | | 600 | 1250 | |
| | 625 | 1300 | | 600 | 1250 | | 600 | 1300 | | 600 | 1400 | |
| | 575 | 1250 | | 600 | 1250 | | 600 | 1250 | | 600 | 1250 | |

Blank spaces indicate where precise measurements were not obtainable.

FIGURE 7

Second element of the complex nuclei compared with simple vowels in the environment /t - n/ Level tone Informant 3

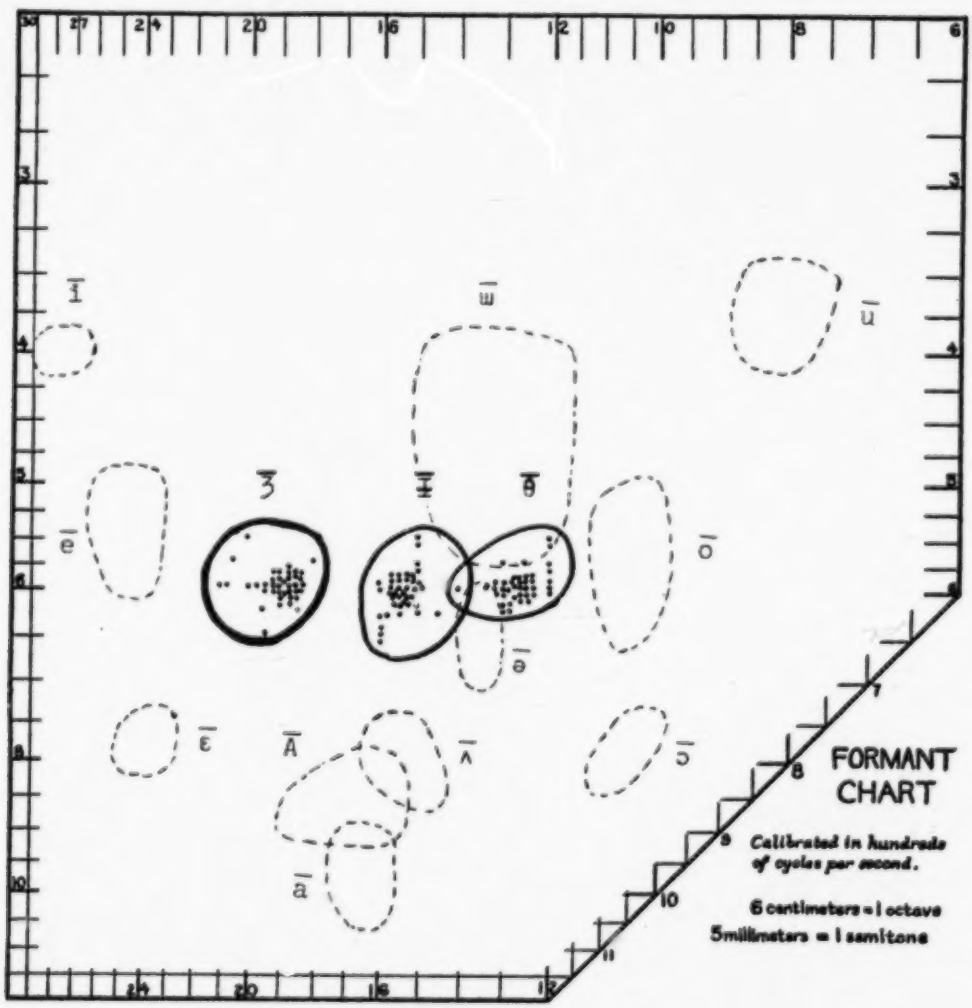


TABLE 8

Second segments of the complex nuclei: Informant 1

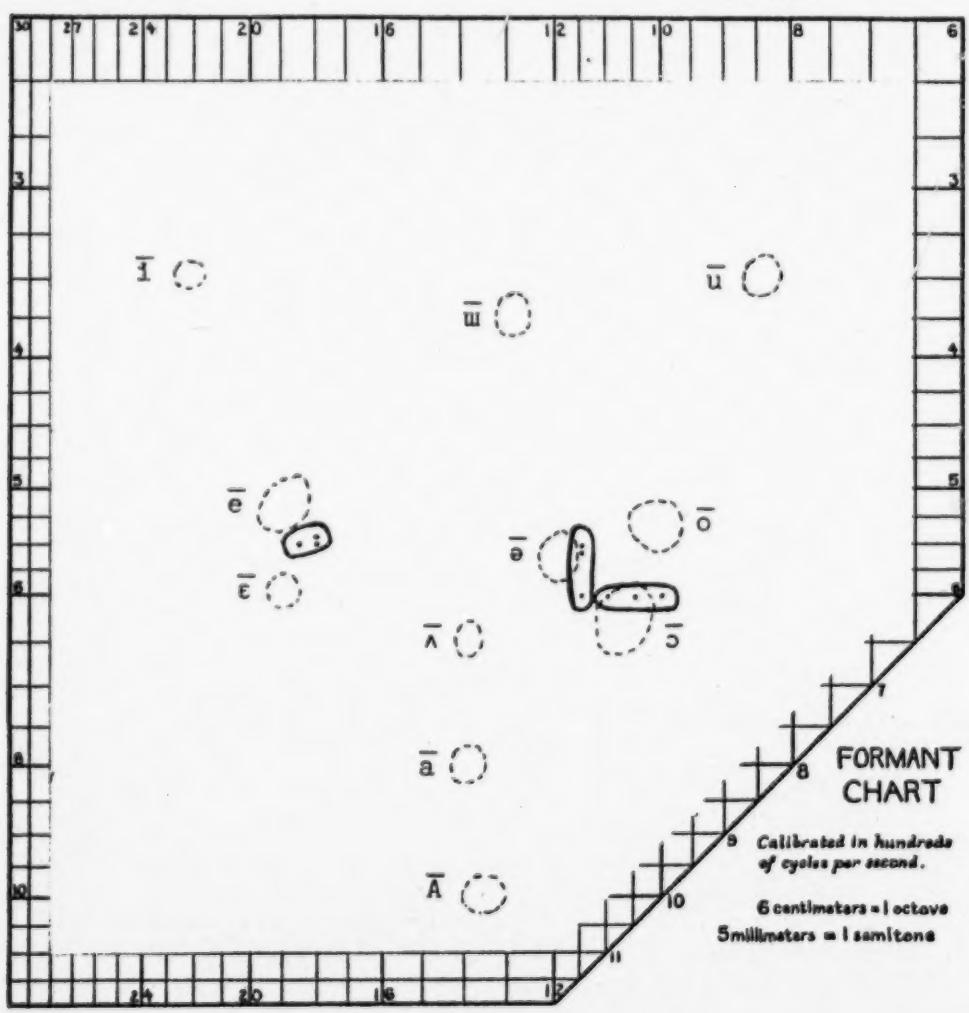
| Word | 1 F1 | F2 | 2 F1 | F2 | 3 F1 | F2 | 4 F1 | F2 |
|---|---|---|---|---|---|---|---|---|
| tɪ̄ʒn | | | 550 | 1800 | 550 | 1800 | 550 | 1850 |
| tɯ̄ɪ̄m | | | 600 | 1150 | 550 | 1150 | 550 | 1150 |
| tʊ̄θn | | | 600 | 1050 | 600 | 1000 | 600 | 1100 |

Blank spaces indicate where precise measurements were not obtainable.

FIGURE 8

Second element of the complex nuclei compared with simple vowels

Level tone Informant 1



are led to the following conclusions:

1) The first segments, tentatively transcribed as [I], [ɯ], and [U] are phonetically similiar enough to [i], [ɯ], and [u] to be regarded as the same vowel qualities. The acoustic phonetic data confirms the auditory impression. The first segments of the complex nuclei are best analysed as /i/, /ɯ/, and /u/ respectively.

2) The second segments of [iɜ], [ɯɪ], and [uθ] in the environment /t - n/ with level tone occupy three distinctive domains on the formant chart. [ɜ] is more similar to /e/, [ɪ] is more similar to /ə/, and [θ] is more similar to /o/ than [ɜ], [I], and [θ] are to each other or to the domain of any one phoneme.

It might be possible to analyse [ɜ], [ɪ], and [θ] as one single phoneme on the basis of their distribution, since [ɜ] occurs only after /i/, [ɪ] only after /ɯ/, and [θ] only after /u/. On a distributional basis they could be assigned as allophones in complementary distribution. Such a phonemic analysis, however, lacks phonetic basis and is close to becoming merely a mentalistic game. After careful observation of the phonetic phenomena, we analyse [ɜ], [ɪ], and [θ] phonemically as /e/, /ə/, and /o/, making the complex nuclei phonemically: /ie/ /ɯə/ and /uo/.

## Chapter 4

## COMPLEX NUCLEI IN VARIED ENVIRONMENTS

As presented in the previous chapter, the acoustic-phonetic study of complex syllable nuclei led us to the analysis of the segments spelled "tiên", "tuɔ̀n", and "tuôn" as /tī̲e̲n/, /tw̲ə̲n/, and /tu̲o̲n/.

The purpose of the present chapter is to test our analysis of [ɜ], [ɪ], and [ɵ] as the three separate phonemes /e/, /ə/, and /o/ in more varied phonetic environments. Also, we will try to answer the question of whether the second segments of each of the following pairs are phonetically similar enough to be considered the same:

| Open syllables | Closed syllables |
|---|---|
| "-ia" | "-iê-" |
| "-uə̀" | "-uɔ̀-" |
| "-ua" | "-uô-" |

As noted earlier, Thompson analysed the second segments [ɜ], [ɪ], and [ɵ] in open syllables as all being the same phoneme /ʌ/, and those in closed syllables as being three separate phonemes /e/, /ə/, and /o/. Other analysts have interpreted the second segments of the pairs spelled "-ia" and "-iê-", "-uə̀" and "-uɔ̀-", and "-ua" and "-uô-" as being

phonemically the same. To arrive at a conclusive answer to this problem, it is necessary to study phonetic differences between the complex nuclei in open syllables and those in closed syllables.

For this study, the recording material was arranged according to syllable types and tones. Six tones, level /–/, rising /⁄/, broken /⁓/, falling /\/, curve /ˇ/, and drop /¬/, are contrastive in the Hanoi dialect of Vietnamese. A syllable in Vietnamese can be open or closed. The final consonants that occur following the three complex nuclei are summarized as follows:

| | p | t | k | m | n | ŋ | w | y |
|---|---|---|---|---|---|---|---|---|
| [iɜ] | + | + | + | + | + | + | + | - |
| [ɯɨ] | + | + | + | + | + | + | + | + |
| [uθ] | - | + | + | + | + | + | - | + |

The distribution of final /y/ and /w/ with complex nuclei is noteworthy. /y/ in Vietnamese follows only the central and back vowels and does not occur after /i/, /e/, /ɛ/, and [iɜ]. /w/ follows only the central and front vowels and does not occur after /u/, /o/, /ɔ/, and [uθ]. This distributional characteristic seems to suggest that [ɜ] is structurally parallel to the front vowel /e/, and [θ] is structurally parallel to the back vowel /o/. However, the phonemic status of /w/ and /y/ as consonants needs further study to confirm this interpretation. We, therefore, decided not to include /w/ and /y/ as consonants in our spectrographic analyses. Our analysis included: 1) open

syllable words grouped according to the six different tones and 2) closed syllable words with final consonants /p t k m n ŋ/, also grouped according to the six tones.

Table 9 represents F1 and F2 measurements of the second segment [ɜ] of [iɜ] in open syllable words as spoken by Informant 4. Figure 9 is the corresponding graphic representation. The [x] represents the measurements of [ɜ] with drop tone, while the dot [.] represents [ɜ] with all other tones. The occurrences of phones having an F1 measurement between 550-600 cps are identified as being either those with drop tone /¬/ or with broken tone /~/. In our previous study, it was observed that drop tone consistently raised F1 measurements of simple vowels 50-100 cps, making the phones with drop tone appear much lower on the formant chart. In Figure 9, the same effect is observed on the formant measurements of [ɜ].

Table 10 summarizes the data obtained from the formant measurements of [ɪ] of [wɪ] in open syllables spoken by Informant 4. When converting the figures into the graphic representation on the formant chart as shown in Figure 10, it became apparent that on this vowel, also, the effect of the drop tone is clearly observable. It is interesting to note that the effect of drop tone on the segments [ɜ] and [ɪ] is very much like that observed on the simple vowels /e/ and /ə/.

It was noted in our previous study that drop tone has slightly less effect on back vowels than on front and central vowels. The extent of the drop tone effect on F1 measurements

TABLE 9

**Formant measurements of complex nuclei segment [ɜ] Open syllable cycles/second**

All tones Informant 4

Segment [ɜ] with tone [-]

| Word | 1 F1 | F2 | F3 | 2 F1 | F2 | F3 | 3 F1 | F2 | F3 | 4 F1 | F2 | F3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| tɜ̄ | 450 | 2050 | | 450 | 2000 | | 450 | 2000 | | 450 | 2050 | |
| tʰɜ̄ | 500 | 1900 | | 450 | 1900 | | 450 | 1950 | | 450 | 1950 | |
| cɜ̄ | 400 | 2200 | | 450 | 2150 | | 450 | 2100 | | 450 | 2000 | |
| kɜ̄ | 450 | 2050 | | 450 | 2000 | | 450 | 2050 | | 450 | 2050 | |
| bɜ̄ | 450 | 2050 | | 450 | 2000 | | 450 | 2050 | | 450 | 1950 | |
| lɜ̄ | 450 | 1900 | | 450 | 1850 | | 450 | 1900 | | 450 | 1850 | |
| nɜ̄ | 450 | 2000 | | 450 | 2000 | | 450 | 2100 | | 450 | 2050 | |
| ɲɜ̄ | 450 | 2000 | | 450 | 2000 | | 450 | 2000 | | 450 | 2000 | |
| vɜ̄ | 450 | 2000 | | 450 | 1850 | | 450 | 1950 | | 450 | 1850 | |
| ɹɜ̄ | 450 | 1900 | | 450 | 1850 | | 450 | 1900 | | 450 | 1550 | |
| ɻɜ̄ | 450 | 2000 | | 450 | 1900 | | 450 | 1900 | | 450 | 1900 | |

Segment [ɜ] with tone [/]

| Word | 1 F1 | F2 | F3 | 2 F1 | F2 | F3 | 3 F1 | F2 | F3 | 4 F1 | F2 | F3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| tɜ́ | 500 | 2000 | | 500 | 1850 | | 450 | 1900 | | 450 | 1950 | |
| mɜ́ | 500 | 2000 | | 450 | 1900 | | 450 | 2050 | | 450 | 2050 | |
| fɜ́ | 500 | 1850 | | 500 | 1950 | | 450 | 2000 | | 450 | 1950 | |
| xɜ́ | 450 | 2050 | | 450 | 2000 | | 450 | 2000 | | 450 | 2050 | |

Segment [ɜ] with tone [\]

| Word | 1 F1 | F2 | F3 | 2 F1 | F2 | F3 | 3 F1 | F2 | F3 | 4 F1 | F2 | F3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| tʰɜ̀ | 450 | 2050 | | 500 | 2000 | | 450 | 2050 | | 450 | 2100 | |
| cɜ̀ | 450 | 2150 | | 500 | 2000 | | 500 | 1950 | | 450 | 2100 | |
| kɜ̀ | 500 | 2000 | | 500 | 1900 | | 500 | 1950 | | 450 | 2000 | |
| bɜ̀ | 450 | 2000 | | 450 | 1900 | | 450 | 2000 | | 450 | 2000 | |
| dɜ̀ | 450 | 1950 | | 450 | 2000 | | 450 | 1900 | | 500 | 1850 | |
| lɜ̀ | 450 | 2000 | | 450 | 1950 | | 450 | 2000 | | 450 | 2000 | |

Segment [ɜ] with tone [~]

| Word | 1 F1 | F2 | F3 | 2 F1 | F2 | F3 | 3 F1 | F2 | F3 | 4 F1 | F2 | F3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| cɜ̃ | 650 | 1950 | | 550 | 1850 | | 600 | 1850 | | 600 | 1850 | |
| dɜ̃ | 600 | 1850 | | 550 | 1800 | | 550 | 1800 | | 600 | 1850 | |
| nɜ̃ | 650 | 1900 | | 550 | 1800 | | 550 | 1900 | | 600 | 1850 | |
| ɲɜ̃ | 600 | 1800 | | 550 | 1900 | | 600 | 1850 | | 600 | 1850 | |

Segment [ɜ] with tone [˜]

| Word | 1 F1 | F2 | F3 | 2 F1 | F2 | F3 | 3 F1 | F2 | F3 | 4 F1 | F2 | F3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ɜ̃ | 450 | 2000 | | 550 | 1900 | | 500 | 2000 | | 400 | 2050 | |
| tɜ̃ | 500 | 2050 | | 450 | 2050 | | 400 | 2000 | | 400 | 2000 | |
| dɜ̃ | 500 | 1900 | | 450 | 1950 | | 500 | 1950 | | 500 | 2000 | |
| mɜ̃ | 550 | 2000 | | 500 | 1950 | | 500 | 2000 | | 500 | 1950 | |

Segment [ɜ] with tone [¬]

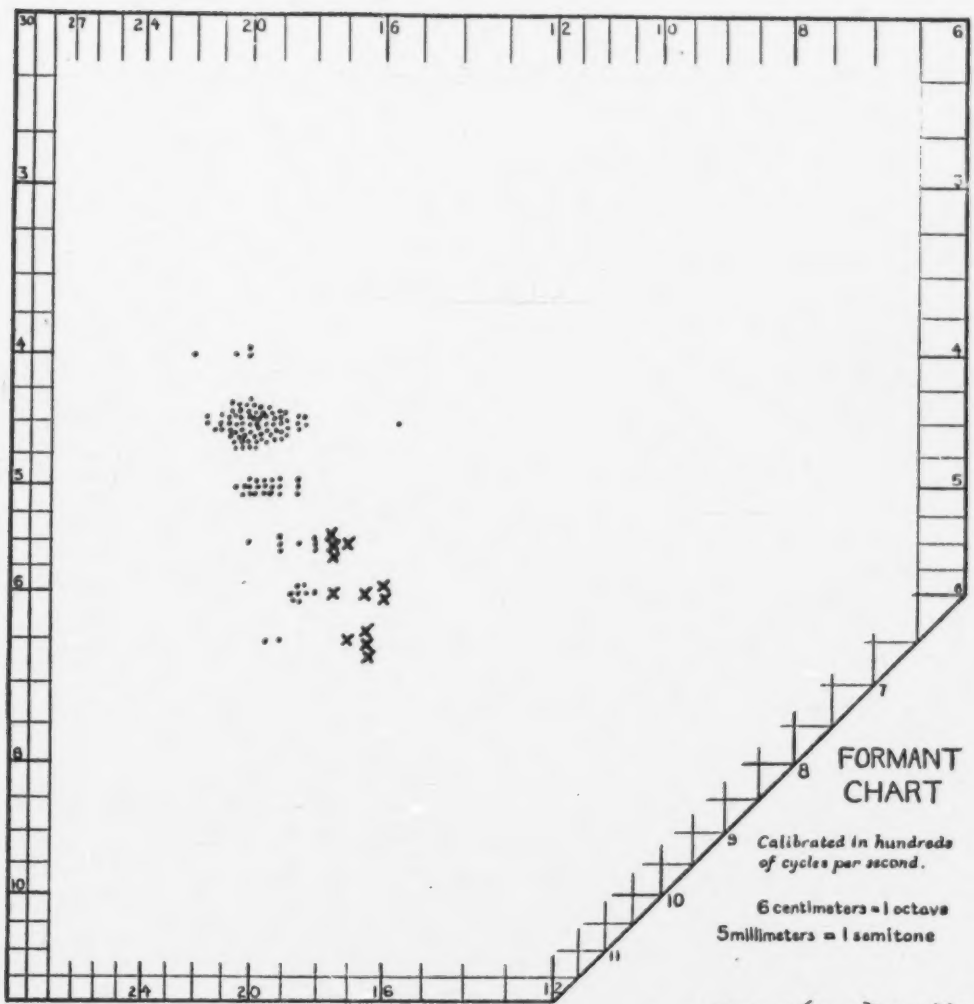
| Word | 1 F1 | F2 | F3 | 2 F1 | F2 | F3 | 3 F1 | F2 | F3 | 4 F1 | F2 | F3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| bɜ̄ | 650 | 1650 | | 650 | 1650 | | 550 | 1750 | | 550 | 1750 | |
| dɜ̄ | 650 | 1700 | | 550 | 1750 | | 550 | 1700 | | 600 | 1750 | |
| lɜ̄ | 650 | 1650 | | 600 | 1600 | | 600 | 1600 | | 600 | 1650 | |

**Blank spaces indicate where precise measurements were not obtainable.**

FIGURE 9

[ʒ] in open syllables

All tones Informant 4




· = [ʒ̄] [ʒ́] [ʒ̀] [ǯ] [ʒ̃]

× = [ʒ̄]

TABLE 10

Formant measurements of complex nuclei segment [ɨ] Open syllable cycles/second

All tones Informant 4

Segment [ɨ] with tone [-]

| Word | 1 F1 | F2 | F3 | 2 F1 | F2 | F3 | 3 F1 | F2 | F3 | 4 F1 | F2 | F3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ɨ̄ | 550 | 1450 | | 550 | 1400 | | 550 | 1400 | | 550 | 1450 | |
| tʰɨ̄ | 550 | 1450 | | 450 | 1450 | | 450 | 1350 | | 550 | 1350 | |
| cɨ̄ | 450 | 1500 | | 500 | 1600 | | 450 | 1650 | | 500 | 1450 | |
| kɨ̄ | 450 | 1400 | | 450 | 1400 | | 450 | 1400 | | 500 | 1450 | |
| dɨ̄ | 550 | 1350 | | 450 | 1500 | | 450 | 1500 | | 500 | 1350 | |
| mɨ̄ | 500 | 1450 | | 500 | 1450 | | 450 | 1450 | | 450 | 1450 | |
| sɨ̄ | 450 | 1450 | | 450 | 1450 | | 450 | 1400 | | 450 | 1400 | |
| zɨ̄ | 500 | 1500 | | 500 | 1500 | | 450 | 1550 | | 450 | 1500 | |

Segment [ɨ] with tone [/]

| Word | 1 F1 | F2 | F3 | 2 F1 | F2 | F3 | 3 F1 | F2 | F3 | 4 F1 | F2 | F3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| cɨ́ | 550 | 1500 | | 450 | 1500 | | 450 | 1500 | | 450 | 1500 | |
| kɨ́ | 600 | 1350 | | 450 | 1350 | | 500 | 1450 | | 450 | 1450 | |
| bɨ́ | 450 | 1400 | | 450 | 1400 | | 450 | 1350 | | 450 | 1400 | |
| dɨ́ | 500 | 1450 | | 500 | 1600 | | 500 | 1450 | | 500 | 1500 | |
| lɨ́ | 500 | 1500 | | 500 | 1450 | | 550 | 1400 | | 500 | 1500 | |
| mɨ́ | 500 | 1450 | | 500 | 1450 | | 500 | 1450 | | 450 | 1400 | |
| nɨ́ | 550 | 1350 | | 500 | 1450 | | 500 | 1450 | | 450 | 1450 | |
| ŋɨ́ | 600 | 1400 | | 500 | 1500 | | 500 | 1500 | | 500 | 1350 | |
| hɨ́ | 500 | 1450 | | 500 | 1350 | | 500 | 1350 | | 500 | 1450 | |

Segment [ɨ] with tone [ˇ]

| Word | 1 F1 | F2 | F3 | 2 F1 | F2 | F3 | 3 F1 | F2 | F3 | 4 F1 | F2 | F3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| tʰɨ̌ | 550 | 1350 | | 500 | 1350 | | 500 | 1350 | | 500 | 1350 | |
| cɨ̌ | 500 | 1450 | | 450 | 1400 | | 500 | 1300 | | 500 | 1400 | |
| bɨ̌ | 600 | 1350 | | 500 | 1500 | | 500 | 1550 | | 450 | 1500 | |
| lɨ̌ | 500 | 1450 | | 550 | 1450 | | 550 | 1400 | | 550 | 1450 | |
| ŋɨ̌ | 550 | 1450 | | 500 | 1350 | | 500 | 1350 | | 550 | 1350 | |

Segment [ɨ] with tone [~]

| Word | 1 F1 | F2 | F3 | 2 F1 | F2 | F3 | 3 F1 | F2 | F3 | 4 F1 | F2 | F3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| cɨ̃ | 550 | 1500 | | 550 | 1550 | | 550 | 1500 | | 550 | 1450 | |
| bɨ̃ | 600 | 1400 | | 550 | 1450 | | 550 | 1400 | | 600 | 1450 | |
| nɨ̃ | 600 | 1450 | | 550 | 1350 | | 600 | 1350 | | 550 | 1400 | |

Segment [ɨ] with tone [⌣]

| Word | 1 F1 | F2 | F3 | 2 F1 | F2 | F3 | 3 F1 | F2 | F3 | 4 F1 | F2 | F3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| cɨ̆ | 600 | 1400 | | 550 | 1500 | | 500 | 1450 | | 500 | 1450 | |
| kɨ̆ | 600 | 1350 | | 550 | 1400 | | 550 | 1350 | | 550 | 1400 | |
| bɨ̆ | 650 | 1350 | | 550 | 1400 | | 500 | 1450 | | 550 | 1350 | |
| mɨ̆ | 550 | 1350 | | 550 | 1350 | | 550 | 1500 | | 550 | 1400 | |
| nɨ̆ | 600 | 1350 | | 550 | 1450 | | 500 | 1500 | | 500 | 1500 | |
| ŋɨ̆ | 600 | 1400 | | 500 | 1500 | | 550 | 1400 | | 550 | 1450 | |

Segment [ɨ] with tone [¬]

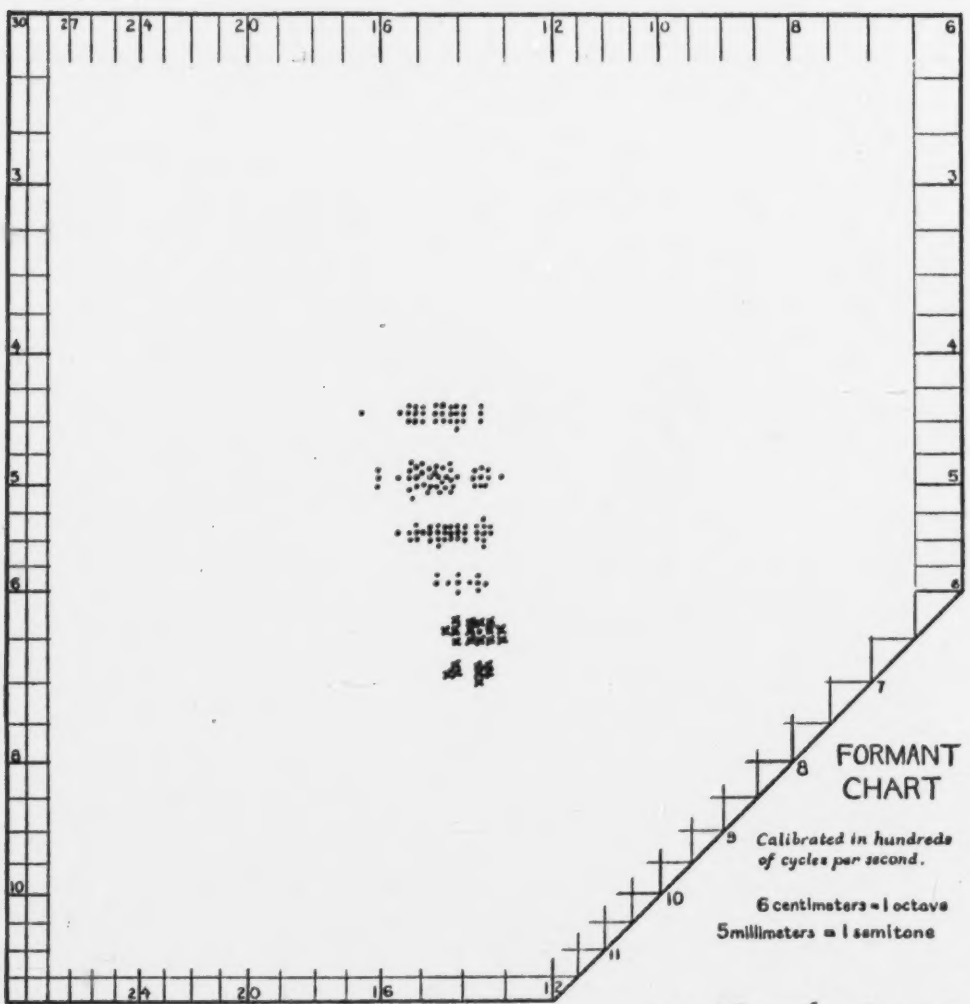
| Word | 1 F1 | F2 | F3 | 2 F1 | F2 | F3 | 3 F1 | F2 | F3 | 4 F1 | F2 | F3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ɨ̄ | 650 | 1300 | | 700 | 1350 | | 700 | 1350 | | 700 | 1350 | |
| tɨ̄ | 650 | 1300 | | 650 | 1400 | | 650 | 1400 | | 650 | 1350 | |
| kɨ̄ | 700 | 1350 | | 650 | 1350 | | 650 | 1300 | | 700 | 1400 | |
| bɨ̄ | 700 | 1400 | | 650 | 1400 | | 650 | 1350 | | 650 | 1350 | |
| lɨ̄ | 700 | 1400 | | 700 | 1350 | | 650 | 1350 | | 650 | 1350 | |
| ŋɨ̄ | 700 | 1350 | | 650 | 1350 | | 650 | 1350 | | 650 | 1400 | |

Blank spaces indicate where precise measurements were not obtainable.

FIGURE 10

[ɪ] in open syllables

All tones Informant 4



of back vowels is approximately 50 cps. Table 11 summarizes the measurements of F1 and F2 of the segment [θ] of [uθ] in open syllables. Figure 11 is the graphic representation of the same measurements. The effect of drop tone on the segment [θ] is seen to be very similar to that observed on the simple vowel /o/.

The domains occupied by [ʒ], [ɪ], and [θ] in open syllables are placed together on one formant chart as shown in Figure 11a. This chart shows that the three sounds do occupy three distinct areas even when the environments of the complex nuclei are enlarged to include all six tones and various initial consonants. This result gives further support to our analysis of [ʒ], [ɪ], and [θ] as three separate phonemes rather than one single phoneme.

TABLE 11

Formant measurements of complex nuclei segment [ʊ̃] Open syllable cycles/second

All tones Informant 4

Segment [ʊ̃] with tone [-]

| Word | 1 F1 | F2 | F3 | 2 F1 | F2 | F3 | 3 F1 | F2 | F3 | 4 F1 | F2 | F3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| tʊ̃ | 550 | 1150 | | 500 | 1150 | | 500 | 1150 | | 500 | 1100 | |
| tʰʊ̃ | 500 | 1000 | | 450 | 1000 | | 450 | 1000 | | 450 | 950 | |
| cʊ̃ | 500 | 1000 | | 450 | 1050 | | 450 | 1050 | | 500 | 1000 | |
| kʊ̃ | 450 | 950 | | 500 | 1050 | | 450 | 1050 | | 450 | 950 | |
| dʊ̃ | 500 | 1000 | | 550 | 1100 | | 550 | 1100 | | 500 | 1000 | |
| mʊ̃ | 450 | 900 | | 450 | 1000 | | 450 | 900 | | 450 | 950 | |
| nʊ̃ | 450 | 950 | | 450 | 950 | | 450 | 1000 | | 450 | 1000 | |
| ŋʊ̃ | 450 | 1000 | | 500 | 1000 | | 550 | 1100 | | 550 | 1100 | |
| fʊ̃ | 500 | 1050 | | 500 | 1000 | | 500 | 1050 | | 450 | 1050 | |
| vʊ̃ | 500 | 1100 | | 450 | 1100 | | 450 | 1000 | | 450 | 1000 | |
| sʊ̃ | 450 | 1050 | | 500 | 1050 | | 500 | 1100 | | 450 | 1100 | |
| zʊ̃ | 450 | 1100 | | 450 | 1050 | | 450 | 1050 | | 450 | 1050 | |
| xʊ̃ | 450 | 1000 | | 500 | 1100 | | 500 | 1050 | | 500 | 1100 | |

Segment [ʊ̃] with tone [/]

| Word | 1 F1 | F2 | F3 | 2 F1 | F2 | F3 | 3 F1 | F2 | F3 | 4 F1 | F2 | F3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ʊ́ | 600 | 1100 | | 550 | 1100 | | 500 | 1100 | | 550 | 1000 | |
| tʊ́ | 500 | 1150 | | 500 | 1150 | | 550 | 1100 | | 500 | 1000 | |
| cʊ́ | 550 | 1150 | | 500 | 1150 | | 450 | 1100 | | 500 | 1150 | |
| bʊ́ | 500 | 1050 | | 450 | 1050 | | 450 | 1100 | | 450 | 1000 | |
| lʊ́ | 450 | 1100 | | 500 | 1000 | | 450 | 1000 | | 450 | 1000 | |
| mʊ́ | 450 | 1050 | | 450 | 1000 | | 450 | 1000 | | 450 | 900 | |

Segment [ʊ̃] with tone [ˇ]

| Word | 1 F1 | F2 | F3 | 2 F1 | F2 | F3 | 3 F1 | F2 | F3 | 4 F1 | F2 | F3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ʊ̌ | 550 | 1150 | | 550 | 1050 | | 550 | 1150 | | 500 | 1100 | |
| tʰʊ̌ | 600 | 1150 | | 600 | 1150 | | 550 | 1100 | | 600 | 1100 | |
| cʊ̌ | 500 | 1100 | | 550 | 1100 | | 550 | 1200 | | 500 | 1100 | |
| bʊ̌ | 550 | 1100 | | 500 | 1100 | | 500 | 1000 | | 500 | 1000 | |
| dʊ̌ | 500 | 1100 | | 450 | 1000 | | 450 | 1000 | | 500 | 1100 | |
| lʊ̌ | 550 | 1150 | | 550 | 1100 | | 550 | 1100 | | 550 | 1100 | |
| mʊ̌ | 500 | 1000 | | 500 | 1100 | | 500 | 1000 | | 500 | 1000 | |

Segment [ʊ̃] with tone [~]

| Word | 1 F1 | F2 | F3 | 2 F1 | F2 | F3 | 3 F1 | F2 | F3 | 4 F1 | F2 | F3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| dʊ̃ | 550 | 1100 | | 600 | 1050 | | 600 | 1100 | | 600 | 1150 | |
| lʊ̃ | 600 | 1150 | | 550 | 1150 | | 500 | 1000 | | 550 | 1150 | |
| zʊ̃ | 550 | 1150 | | 550 | 1100 | | 550 | 1150 | | 600 | 1150 | |

Segment [ʊ̃] with tone [˘]

| Word | 1 F1 | F2 | F3 | 2 F1 | F2 | F3 | 3 F1 | F2 | F3 | 4 F1 | F2 | F3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ʊ̆ | 600 | 1050 | | 600 | 1100 | | 550 | 1050 | | 600 | 1050 | |
| kʊ̆ | 550 | 1050 | | 500 | 1050 | | 550 | 1000 | | 500 | 1000 | |
| sʊ̆ | 600 | 1150 | | 550 | 1100 | | 550 | 1050 | | 550 | 1050 | |
| zʊ̆ | 550 | 1150 | | 500 | 1100 | | 550 | 1100 | | 500 | 1000 | |

Segment [ʊ̃] with tone [¯]

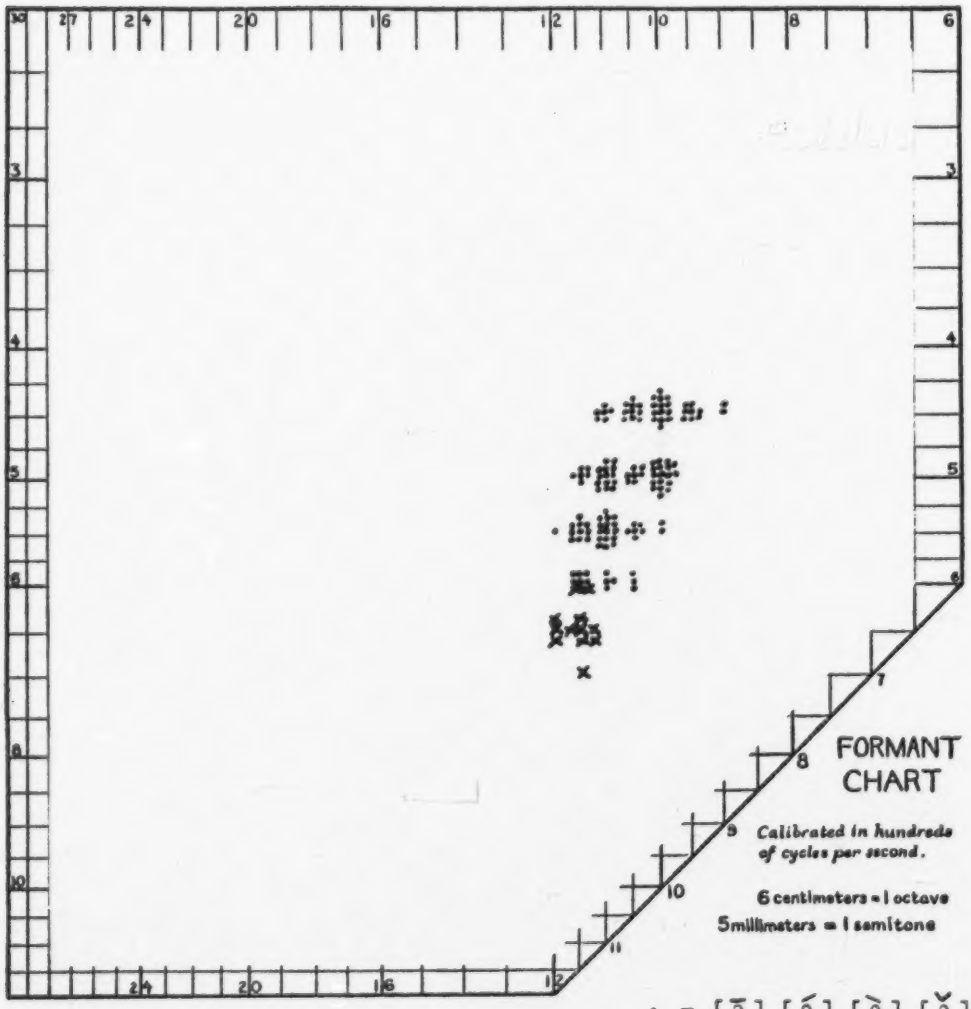
| Word | 1 F1 | F2 | F3 | 2 F1 | F2 | F3 | 3 F1 | F2 | F3 | 4 F1 | F2 | F3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ʊ̄ | 650 | 1150 | | 650 | 1150 | | 650 | 1200 | | 650 | 1200 | |
| bʊ̄ | 650 | 1150 | | 650 | 1150 | | 650 | 1150 | | 650 | 1200 | |
| lʊ̄ | 700 | 1150 | | 650 | 1150 | | 600 | 1150 | | 600 | 1150 | |

Blank spaces indicate where precise measurements were not obtainable.

FIGURE 11

[θ] in open syllables

All tones Informant 4



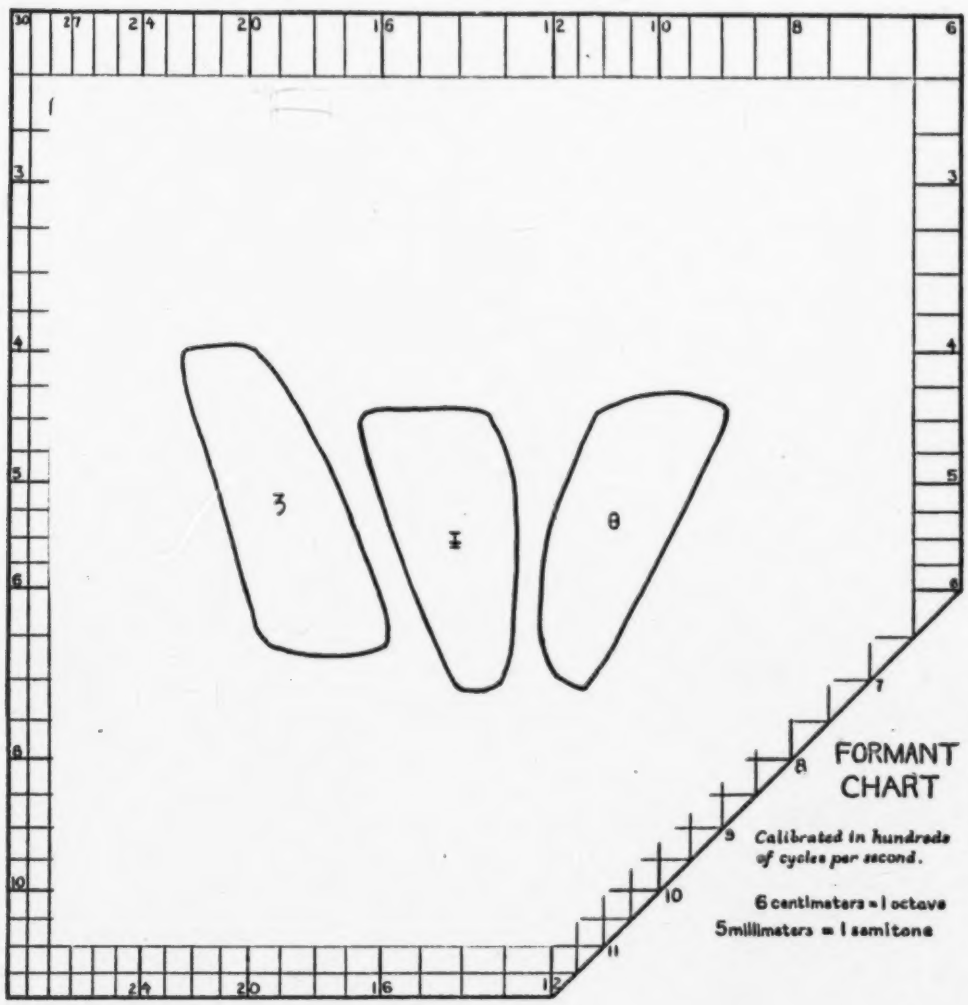

· = [θ̄] [θ́] [θ̀] [θ̌] [θ̃]

× = [θ̿]

FIGURE 11a

Domains of [-ʒ] [-ɪ] [-θ] in open syllables

All tones Informant 4



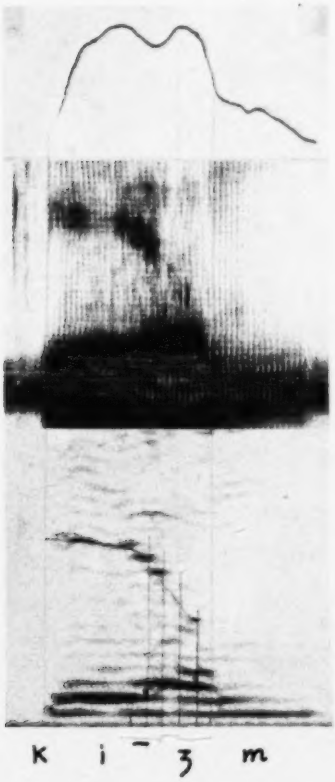
Different final consonants have varying effects on the quality of the syllable nuclei. These differences are observable in the frequency and shapes of formants. Spectrograms 16-19 illustrate the differences in formant shapes of [iɜ] in an open syllable, such as [kiɜ], and in closed syllables with the final consonants [-n], [-m], and [-ŋ], as in [kiɜ̄n], [kiɜ̄m], and [kiɜ̄ŋ]. As is easily seen on these spectrograms, the complex nuclei [iɜ] in the open syllable has a steady state of [i] and a steady state of [ɜ]. When there is such a steady state on the spectrogram of a vocalic quality, this point is taken as the most reasonable place to measure the formant. In the case of closed syllables, as seen on the spectrograms of [kiɜ̄n], [kiɜ̄m], and [kiɜ̄ŋ], the second segment [ɜ] is usually shorter than the first segment [i] and usually has no observable steady state. In the case of continually changing formants such as these, it is difficult to determine where the formant measurements should be taken, because a small difference in time may result in a large difference in F1 and F2 mesurements. For this reason, we applied the use of an amplitude display unit in determining the point where F1 and F2 measurements should be taken. Table 12 shows F1 and F2 measurements taken at intervals of two centiseconds along the relatively steady states of the formants of [i] and of [ɜ] in [kiɜ] and, also, those measurements taken along the continually changing formants of [i] and [ɜ] of [kiɜ̄n], [kiɜ̄m], and [kiɜ̄ŋ]. Figure 12a shows a diagrammed interpretation of the formant

SPECTROGRAM NO. 16

Informant 4

SPECTROGRAM NO. 17

SPECTROGRAM NO. 18




SPECTROGRAM NO. 19

TABLE 12

Formant measurements at intervals of 2 centiseconds

Complex nuclei [$\overline{\text{i}}\overline{\text{ɜ}}$] Informant 4 cycles/second

| Word | [kī$\overline{\text{ɜ}}$] | | [kī$\overline{\text{ɜ}}$n] | | [kī$\overline{\text{ɜ}}$m] | | [kī$\overline{\text{ɜ}}$ŋ] | |
|---|---|---|---|---|---|---|---|---|
| csec. | F1 | F2 | F1 | F2 | F1 | F2 | F1 | F2 |
| 0 | 300 | 2250 | 300 | 2350 | 300 | 2200 | 300 | 2200 |
| 2 | 300 | 2250 | 300 | 2350 | 350 | 2200 | 350 | 2200 |
| 4 | 300 | 2250 | 300 | 2350 | 350 | 2200 | 350 | 2200 |
| 6 | 300 | 2250 | 300 | 2300 | 350 | 2150 | 350 | 2200 |
| 8 | 300 | 2250 | 350 | 2250 | 350 | 2100 | 350 | 2150 |
| 10 | 300 | 2250 | 400 | 2100 | 350 | 2050 | 350 | 2150 |
| 12 | 300 | 2200 | 450 | 2050 | 400 | 1950 | 400 | 2000 |
| 14 | 300 | 2150 | 500 | 1950 | 500 | 1800 | 500 | 1950 |
| 16 | 350 | 2050 | 500 | 1900 | 500 | 1400 | 500 | 1750 |
| 18 | 450 | 2000 | 500 | 1850 | 550 | 1250 | 550 | 1550 |
| 20 | 450 | 2000 | | | | | 600 | 1500 |
| 22 | 450 | 2000 | | | | | | |
| 24 | 450 | 2000 | | | | | | |
| 26 | 450 | 2000 | | | | | | |

Blank spaces indicate where precise measurements were not obtainable.

measurements, with an x marking the point of the amplitude peak of the segment [ɜ]. Figure 12b shows how these measurements would be interpreted on formant charts. Table 12 and Figure 12a and 12b show the varying effects of different final consonants on the complex nuclei.

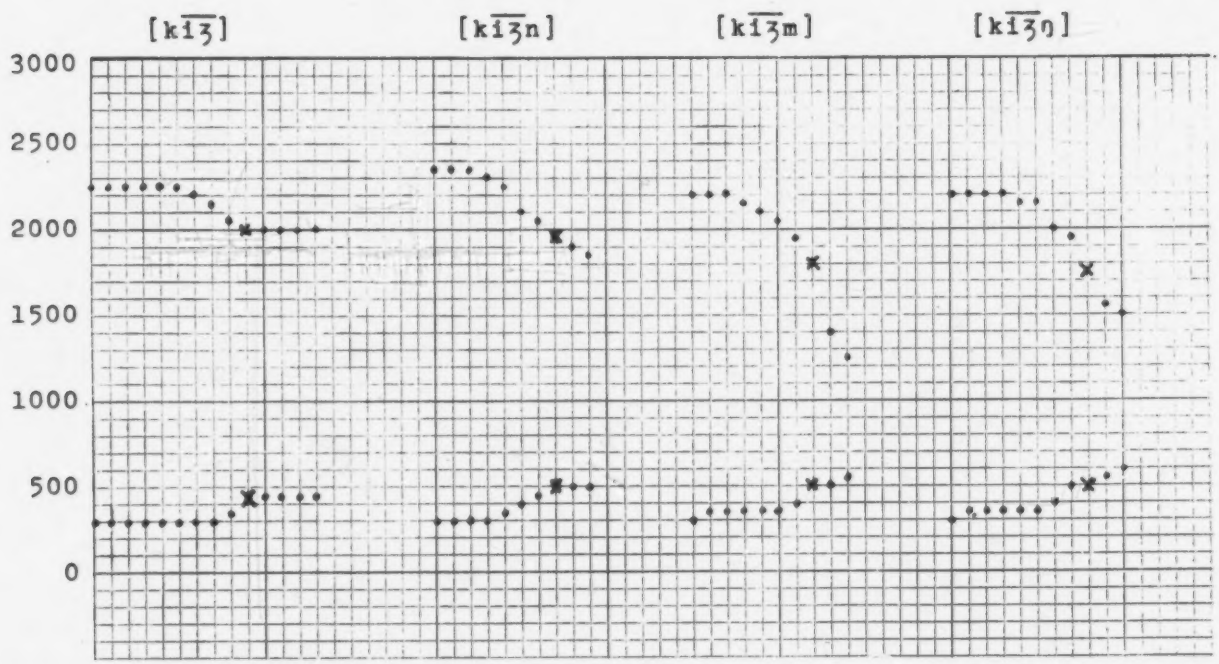
In a complex nucleus, there usually are two amplitude peaks; whereas, in a simple vowel nucleus, there is only one amplitude peak. The two amplitude peaks of a complex nucleus normally coincide in time with the mid-points of the first and the second segments of the nucleus. The mid-point and amplitude peak of the first segment also coincide with the steady state of that segment. This suggests that the point where the second amplitude peak occurs is the target point or near it, and therefore is the most logical place to measure F1 and F2 of the second segment. Using this reasoning, the measurements presented in the following tables were obtained at the point of the second amplitude peak.

Table 13 presents the F1 and F2 measurements of the segment [ɜ] of [iɜ] in closed syllables with /-m, -n, -ŋ, -p, -t, -k/ as the final consonants. All tones are represented here in the utterances spoken by Informant 4. Figure 13 is the graphic representation of the figures presented in Table 13. It may be noted that the domain of [ɜ] is slightly larger and more centralized in these examples than is the domain of [ɜ] in open syllables.

FIGURE 12a

F1 and F2 of complex nucleus [iʒ]
in different environments

Informant 4

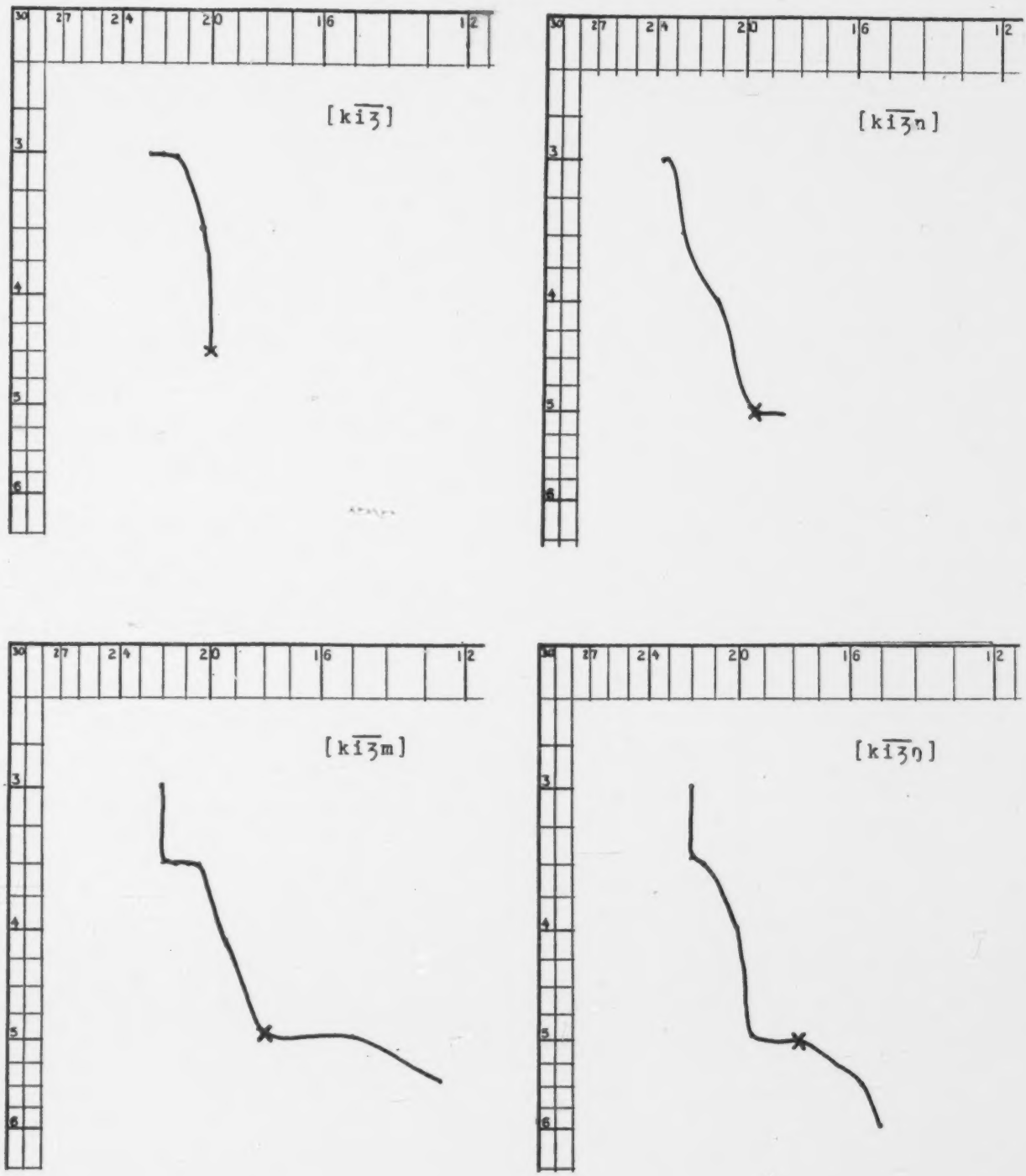



x marks the amplitude peak of segment [-ʒ]

FIGURE 12b

Formant movements in complex nucleus [iʒ]

Informant 4




x marks the amplitude peak of segment [-ʒ]

TABLE 13

Formant measurements of complex nuclei segment [ɜ] Closed syllable cycles/second
All tones Informant 4

Segment [ɜ˥] with tone [˥]

| Word | 1 F1 | F2 | F3 | 2 F1 | F2 | F3 | 3 F1 | F2 | F3 | 4 F1 | F2 | F3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ɪ̃ɜ̃ɲ | 600 | 1700 | | 600 | 1500 | | 600 | 1500 | | 600 | 1500 | |
| tɪ̃ɜ̃n | 600 | 1900 | | 600 | 1500 | | 550 | 1500 | | 550 | 1500 | |
| kɪ̃ɜ̃m | | | | 600 | 1500 | | 550 | 1500 | | 500 | 1550 | |
| lɪ̃ɜ̃ŋ | 600 | 1950 | | 600 | 1500 | | 600 | 1500 | | 600 | 1500 | |
| nɪ̃ɜ̃m | | | | 600 | 1600 | | 550 | 1600 | | 550 | 1600 | |
| ŋɪ̃ɜ̃m | | | | 550 | 1550 | | 550 | 1600 | | 500 | 1650 | |
| ɪ̃ɜ̃n | 550 | 1900 | | 600 | 1900 | | 550 | 1950 | | 600 | 1900 | |
| tɪ̃ɜ̃n | 550 | 1900 | | 550 | 1900 | | 550 | 1950 | | 600 | 1850 | |
| kɪ̃ɜ̃n | 550 | 1950 | | 500 | 1950 | | 450 | 1950 | | 450 | 1950 | |
| nɪ̃ɜ̃n | 550 | 1950 | | 550 | 1900 | | 500 | 1950 | | 600 | 1850 | |
| ɡɪ̃ɜ̃n | 550 | 1850 | | 500 | 1900 | | 500 | 1900 | | 500 | 1900 | |
| nɪ̃ɜ̃n | | | | 550 | 1950 | | 600 | 1900 | | 600 | 1850 | |
| xɪ̃ɜ̃n | 550 | 2000 | | 450 | 2000 | | 550 | 2000 | | 450 | 1950 | |
| nɪ̃ɜ̃n | | | | 450 | 1950 | | 450 | 1950 | | 450 | 1950 | |
| ŋɪ̃ɜ̃n | | | | 550 | 1950 | | 550 | 1900 | | 550 | 1900 | |
| tʰɪ̃ɜ̃n | 550 | 1600 | | 550 | 1650 | | 500 | 1600 | | 550 | 1600 | |
| cɪ̃ɜ̃ŋ | | | | 550 | 1600 | | 550 | 1700 | | 550 | 1550 | |
| kɪ̃ɜ̃ŋ | | | | 600 | 1600 | | 550 | 1650 | | 550 | 1700 | |
| ŋɪ̃ɜ̃ŋ | | | | 550 | 1750 | | 550 | 1750 | | 550 | 1750 | |
| xɪ̃ɜ̃ŋ | | | | 500 | 1500 | | 450 | 1500 | | 500 | 1550 | |

Segment [ɜ] with tone [˧˥]

| Word | 1 F1 | F2 | F3 | 2 F1 | F2 | F3 | 3 F1 | F2 | F3 | 4 F1 | F2 | F3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| tɪ̌ɜ̌m | 650 | 1500 | | 650 | 1500 | | 600 | 1500 | | 600 | 1550 | |
| tʰɪ̌ɜ̌m | 600 | 1500 | | 600 | 1500 | | 550 | 1550 | | 600 | 1600 | |
| lɪ̌ɜ̌m | 600 | 1400 | | 600 | 1500 | | 600 | 1450 | | 600 | 1500 | |
| nɪ̌ɜ̌m | 650 | 1450 | | 600 | 1500 | | 600 | 1500 | | 600 | 1500 | |
| tɪ̌ɜ̌n | 600 | 1900 | | 600 | 1850 | | 600 | 1900 | | 600 | 1950 | |
| tʰɪ̌ɜ̌n | 550 | 1850 | | 550 | 1950 | | 550 | 1900 | | 600 | 1900 | |
| lɪ̌ɜ̌n | 600 | 1850 | | 600 | 1850 | | 600 | 1900 | | 600 | 1900 | |
| nɪ̌ɜ̌n | 600 | 1850 | | 600 | 1900 | | 600 | 1850 | | 600 | 1950 | |

Segment [ɜ] with tone [˧˩]

| Word | 1 F1 | F2 | F3 | 2 F1 | F2 | F3 | 3 F1 | F2 | F3 | 4 F1 | F2 | F3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| lɪ̂ɜ̂m | 550 | 1500 | | 600 | 1450 | | 600 | 1400 | | 600 | 1500 | |
| nɪ̂ɜ̂m | 550 | 1550 | | 550 | 1500 | | 550 | 1550 | | 550 | 1550 | |
| tɪ̂ɜ̂n | 550 | 1900 | | 550 | 1950 | | 550 | 1950 | | 500 | 2000 | |
| lɪ̂ɜ̂n | 550 | 1950 | | 550 | 1900 | | 550 | 1950 | | 550 | 1900 | |
| nɪ̂ɜ̂n | 550 | 1900 | | 550 | 1950 | | 550 | 2000 | | 550 | 1950 | |
| nɪ̂ɜ̂ŋ | 600 | 1600 | | 600 | 1750 | | 600 | 1750 | | 600 | 1800 | |

Segment [ɜ] with tone [˨]

| Word | 1 F1 | F2 | F3 | 2 F1 | F2 | F3 | 3 F1 | F2 | F3 | 4 F1 | F2 | F3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ɣ̆ɜ̆m | 600 | 1500 | | 550 | 1550 | | 550 | 1600 | | 550 | 1600 | |
| tʰɣ̆ɜ̆m | 650 | 1550 | | 600 | 1550 | | 650 | 1500 | | 600 | 1500 | |
| kɣ̆ɜ̆m | 600 | 1450 | | 550 | 1450 | | 550 | 1500 | | 550 | 1500 | |
| zɣ̆ɜ̆m | 600 | 1500 | | 550 | 1550 | | 550 | 1500 | | 600 | 1500 | |
| tʰɣ̆ɜ̆n | 600 | 1900 | | 550 | 1900 | | 600 | 1900 | | 550 | 1950 | |
| ɣ̆ɜ̆ŋ | 650 | 1700 | | 600 | 1800 | | 550 | 1800 | | 600 | 1750 | |

Blank spaces indicate where precise measurements were not obtainable.

Segment [ɜ] with tone [ ]

| Word | 1 F1 | F2 | F3 | 2 F1 | F2 | F3 | 3 F1 | F2 | F3 | 4 F1 | F2 | F3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| tʃɜ̄p | 500 | 1700 | | 550 | 1700 | | 500 | 1750 | | 550 | 1700 | |
| tʰʃɜ̄p | 500 | 1650 | | 550 | 1650 | | 500 | 1650 | | 550 | 1700 | |
| cʃɜ̄p | 500 | 1700 | | 500 | 1700 | | 500 | 1700 | | 550 | 1700 | |
| kʃɜ̄p | 500 | 1650 | | 500 | 1700 | | 500 | 1750 | | 500 | 1750 | |
| pʃɜ̄p | 550 | 1750 | | 500 | 1800 | | 500 | 1750 | | 500 | 1750 | |
| ʃɜ̄t | 500 | 2000 | | 500 | 2000 | | 500 | 1950 | | 500 | 1950 | |
| tʃɜ̄t | 500 | 1900 | | 550 | 1950 | | 550 | 1950 | | 550 | 1950 | |
| tʰʃɜ̄t | 550 | 1900 | | 500 | 1950 | | 500 | 1850 | | 500 | 1950 | |
| bʃɜ̄t | 500 | 2000 | | 500 | 1950 | | 500 | 1950 | | 500 | 1900 | |
| nʃɜ̄t | 500 | 2000 | | 500 | 2000 | | 500 | 1950 | | 550 | 1850 | |
| tʃɜ̄k | 500 | 1700 | | 500 | 1750 | | 550 | 1750 | | 500 | 1800 | |
| tʰʃɜ̄k | 500 | 1750 | | 500 | 1750 | | 500 | 1750 | | 500 | 1750 | |
| cʃɜ̄k | 550 | 1650 | | 550 | 1750 | | 500 | 1800 | | 550 | 1700 | |
| bʃɜ̄k | 550 | 1750 | | 550 | 1750 | | 550 | 1850 | | 500 | 1800 | |
| dʃɜ̄k | 550 | 1700 | | 500 | 1750 | | 500 | 1800 | | 500 | 1800 | |
| nʃɜ̄k | 550 | 1800 | | 500 | 1800 | | 500 | 1750 | | 500 | 1750 | |
| ʃɜ̄m | 450 | 1500 | | 550 | 1600 | | 550 | 1500 | | 500 | 1600 | |
| tʃɜ̄m | 550 | 1500 | | 550 | 1500 | | 550 | 1500 | | 500 | 1500 | |
| kʃɜ̄m | 500 | 1550 | | 450 | 1550 | | 450 | 1750 | | 450 | 1600 | |
| bʃɜ̄m | 550 | 1500 | | 550 | 1500 | | 550 | 1500 | | 550 | 1500 | |
| lʃɜ̄m | 500 | 1550 | | 500 | 1550 | | 450 | 1600 | | 550 | 1500 | |
| ʃɜ̄n | 550 | 1900 | | 550 | 1950 | | 550 | 1950 | | 550 | 2000 | |
| tʃɜ̄n | 500 | 1950 | | 500 | 1950 | | 500 | 1900 | | 550 | 1900 | |
| tʰʃɜ̄n | 550 | 1900 | | 550 | 1900 | | 500 | 1900 | | 550 | 1900 | |
| lʃɜ̄n | 550 | 1900 | | 500 | 1850 | | 550 | 1900 | | 550 | 1900 | |
| ŋʃɜ̄n | 550 | 1950 | | 550 | 1950 | | 550 | 2000 | | 550 | 1950 | |
| tʃɜ̄ŋ | 550 | 1550 | | 550 | 1600 | | 550 | 1600 | | 550 | 1600 | |
| bʃɜ̄ŋ | 550 | 1600 | | 550 | 1650 | | 550 | 1750 | | 550 | 1650 | |
| dʃɜ̄ŋ | 550 | 1600 | | 500 | 1700 | | 500 | 1700 | | 550 | 1650 | |
| mʃɜ̄ŋ | 500 | 1600 | | 450 | 1800 | | 450 | 1800 | | 450 | 1850 | |
| vʃɜ̄ŋ | 550 | 1650 | | 550 | 1700 | | 550 | 1700 | | 500 | 1800 | |

Segment [ɜ] with tone [˧˥]

| Word | 1 F1 | F2 | F3 | 2 F1 | F2 | F3 | 3 F1 | F2 | F3 | 4 F1 | F2 | F3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| tʃɜ̌p | 600 | 1650 | | 600 | 1750 | | 600 | 1650 | | 550 | 1650 | |
| dʃɜ̌p | 550 | 1650 | | 600 | 1550 | | 550 | 1600 | | 500 | 1700 | |
| ŋʃɜ̌p | 600 | 1700 | | 550 | 1750 | | 550 | 1800 | | 500 | 1750 | |
| tʃɜ̌t | 550 | 1750 | | 550 | 1850 | | 550 | 1800 | | 550 | 1800 | |
| tʰʃɜ̌t | 550 | 1800 | | 550 | 1700 | | 500 | 1750 | | 550 | 1800 | |
| nʃɜ̌t | 550 | 1850 | | 550 | 1900 | | 550 | 1900 | | 550 | 1900 | |
| ŋʃɜ̌t | 550 | 1800 | | 550 | 1850 | | 550 | 1800 | | 550 | 1800 | |
| tʃɜ̌k | 600 | 1700 | | 550 | 1700 | | 600 | 1700 | | 600 | 1700 | |
| vʃɜ̌k | 600 | 1650 | | 600 | 1700 | | 550 | 1750 | | 550 | 1700 | |
| tʃɜ̌m | 650 | 1400 | | 600 | 1450 | | 600 | 1450 | | 650 | 1450 | |
| nʃɜ̌m | 650 | 1450 | | 600 | 1500 | | 600 | 1500 | | 600 | 1500 | |
| ŋʃɜ̌m | 650 | 1450 | | 600 | 1500 | | 600 | 1500 | | 600 | 1500 | |
| tʃɜ̌n | 600 | 1850 | | 600 | 1850 | | 600 | 1800 | | 600 | 1800 | |
| tʰʃɜ̌n | 600 | 1850 | | 600 | 1800 | | 600 | 1850 | | 600 | 1850 | |
| lʃɜ̌ŋ | 700 | 1500 | | 650 | 1500 | | 700 | 1500 | | 650 | 1500 | |

FIGURE 13

[ɜ] in closed syllables

All tones Informant 4

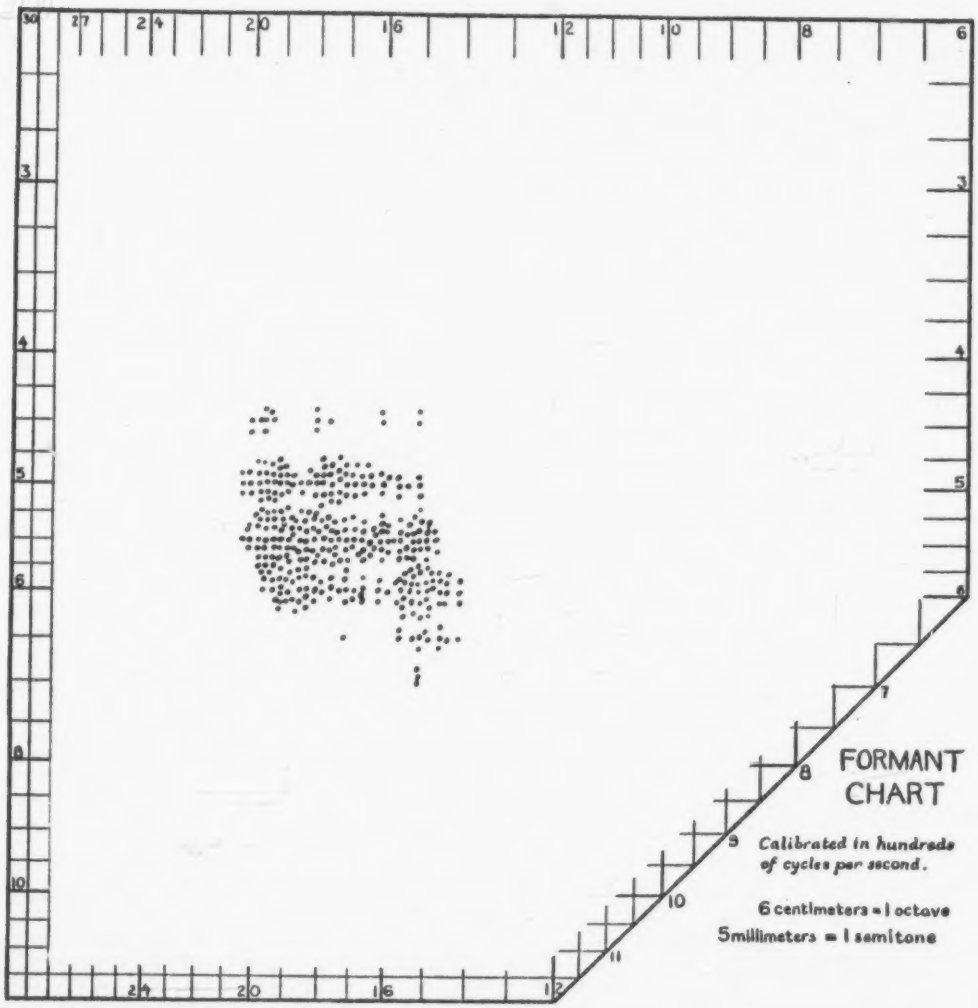


Table 14 presents the F1 and F2 measurements of the segment [ɨ] of [wɨ] in closed syllables with /-m, -n, -ŋ, -p, -t, -k/ as the final consonants. All tones are represented in these utterances by Informant 4. Figure 14 is the corresponding graphic representation of the figures presented in Table 14. It may be noted that the domain of [ɨ] in these examples of the nucleus in closed syllables is slightly larger and extends further back than does the domain of [ɨ] in open syllables.

Table 15 presents the F1 and F2 measurements of [ɵ] of [uɵ] in closed syllables with the same final consonants, and with all tones as spoken by Informant 4. Figure 15 is the corresponding graphic representation on the formant chart. It may be noted that, here again, the domain of [ɵ] covers a slightly larger area and extends further back on the formant chart.

Figure 15a is a composite chart showing all three nuclei segments [ʒ], [ɨ], and [ɵ] in a variety of environments. Some overlap of the three is seen in this presentation; but on careful examination, it is clear that this overlap is regularly conditioned. Three different environments are included on this chart. The small dark areas indicate the domains of [ʒ], [ɨ], and [ɵ] in the restricted environment [t-n] with level tone. The larger striped areas indicate the domains of [ʒ], [ɨ], and [ɵ] in open syllables with all six tones. The very large white areas show the domains of [ʒ], [ɨ], and [ɵ] in closed syllable

TABLE 14

Formant measurements of complex nuclei segment [ɨ] Closed syllable cycles/second

All tones Informant 4

Segment [ɨ] with tone [-]

| Word | 1 F1 | F2 | F3 | 2 F1 | F2 | F3 | 3 F1 | F2 | F3 | 4 F1 | F2 | F3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| tɯ̄ɨm | 550 | 1150 | | 500 | 1200 | | 550 | 1200 | | 550 | 1200 | |
| nɯ̄ɨm | 550 | 1150 | | 550 | 1200 | | 550 | 1200 | | 550 | 1150 | |
| ɲɯ̄ɨm | 500 | 1150 | | 500 | 1200 | | 500 | 1200 | | 500 | 1150 | |
| ɯ̄ɨn | 600 | 1400 | | 600 | 1400 | | 600 | 1400 | | 600 | 1350 | |
| lɯ̄ɨn | 550 | 1450 | | 500 | 1400 | | 500 | 1500 | | 550 | 1450 | |
| tɯ̄ɨŋ | 600 | 1200 | | 600 | 1200 | | 600 | 1200 | | 550 | 1200 | |
| cɯ̄ɨŋ | 650 | 1200 | | 650 | 1250 | | 550 | 1250 | | 650 | 1250 | |
| kɯ̄ɨŋ | 600 | 1150 | | 600 | 1200 | | 600 | 1200 | | 600 | 1250 | |
| bɯ̄ɨŋ | 600 | 1250 | | 500 | 1250 | | 500 | 1250 | | 500 | 1250 | |
| dɯ̄ɨŋ | 550 | 1200 | | 500 | 1200 | | 500 | 1250 | | 500 | 1250 | |
| lɯ̄ɨŋ | 550 | 1200 | | 500 | 1200 | | 450 | 1300 | | 500 | 1200 | |
| mɯ̄ɨŋ | 650 | 1200 | | 550 | 1200 | | 500 | 1300 | | 550 | 1300 | |
| nɯ̄ɨŋ | 600 | 1200 | | 600 | 1250 | | 600 | 1250 | | 600 | 1200 | |
| ɲɯ̄ɨŋ | 600 | 1200 | | 600 | 1250 | | 600 | 1200 | | 550 | 1200 | |
| hɯ̄ɨŋ | 650 | 1150 | | 550 | 1150 | | 500 | 1150 | | 550 | 1250 | |

Segment [ɨ] with tone [ˊ]

| Word | 1 F1 | F2 | F3 | 2 F1 | F2 | F3 | 3 F1 | F2 | F3 | 4 F1 | F2 | F3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| cɯ́ɨm | 550 | 1100 | | 550 | 1100 | | 600 | 1150 | | 600 | 1150 | |
| kɯ́ɨm | 550 | 1100 | | 550 | 1150 | | 550 | 1100 | | 550 | 1150 | |
| nɯ́ɨm | 600 | 1200 | | 600 | 1150 | | 600 | 1250 | | 600 | 1250 | |
| zɯ́ɨm | 600 | 1150 | | 550 | 1100 | | 600 | 1250 | | 550 | 1200 | |
| cɯ́ɨn | 600 | 1450 | | 600 | 1400 | | 550 | 1350 | | 600 | 1350 | |
| vɯ́ɨn | 600 | 1450 | | 600 | 1450 | | 600 | 1450 | | 550 | 1450 | |
| sɯ́ɨn | 600 | 1400 | | 550 | 1400 | | 550 | 1450 | | 600 | 1450 | |
| tɯ́ɨŋ | 650 | 1250 | | 650 | 1200 | | 600 | 1250 | | 600 | 1250 | |
| cɯ́ɨŋ | 600 | 1250 | | 600 | 1250 | | 600 | 1250 | | 600 | 1250 | |
| kɯ́ɨŋ | 650 | 1200 | | 600 | 1200 | | 650 | 1250 | | 650 | 1250 | |
| dɯ́ɨŋ | 650 | 1200 | | 600 | 1200 | | 600 | 1200 | | 600 | 1200 | |
| lɯ́ɨŋ | 600 | 1250 | | 650 | 1200 | | 600 | 1200 | | 600 | 1250 | |
| mɯ́ɨŋ | 650 | 1200 | | 600 | 1200 | | 600 | 1250 | | 600 | 1250 | |
| nɯ́ɨŋ | 650 | 1200 | | 650 | 1200 | | 650 | 1200 | | 650 | 1250 | |
| hɯ́ɨŋ | 600 | 1250 | | 550 | 1150 | | 600 | 1150 | | 650 | 1200 | |

Segment [ɨ] with tone [ˇ]

| Word | 1 F1 | F2 | F3 | 2 F1 | F2 | F3 | 3 F1 | F2 | F3 | 4 F1 | F2 | F3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| tɯ̌ɨŋ | 600 | 1200 | | 550 | 1200 | | 550 | 1150 | | 550 | 1150 | |
| tʰɯ̌ɨŋ | 650 | 1250 | | 600 | 1200 | | 550 | 1150 | | 550 | 1200 | |
| cɯ̌ɨŋ | 650 | 1200 | | 600 | 1200 | | 600 | 1250 | | 600 | 1250 | |
| sɯ̌ɨŋ | 550 | 1150 | | 500 | 1100 | | 550 | 1150 | | 500 | 1100 | |
| hɯ̌ɨŋ | 600 | 1150 | | 600 | 1150 | | 600 | 1150 | | 600 | 1200 | |

Segment [ɨ] with tone [ˋ]

| Word | 1 F1 | F2 | F3 | 2 F1 | F2 | F3 | 3 F1 | F2 | F3 | 4 F1 | F2 | F3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| bɯ̀ɨm | 550 | 1100 | | 550 | 1150 | | 550 | 1150 | | 550 | 1100 | |
| mɯ̀ɨn | 600 | 1550 | | 600 | 1600 | | 600 | 1500 | | 550 | 1450 | |
| bɯ̀ɨŋ | 550 | 1150 | | 600 | 1200 | | 600 | 1200 | | 550 | 1150 | |
| nɯ̀ɨŋ | 550 | 1150 | | 600 | 1200 | | 600 | 1200 | | 550 | 1150 | |
| hɯ̀ɨŋ | 550 | 1200 | | 550 | 1100 | | 550 | 1150 | | 600 | 1200 | |
| ɯ̀ɨp | 600 | 1150 | | 600 | 1300 | | 500 | 1200 | | 600 | 1300 | |
| kɯ̀ɨp | 600 | 1200 | | 550 | 1250 | | 550 | 1200 | | 600 | 1150 | |
| mɯ̀ɨp | 550 | 1200 | | 550 | 1150 | | 500 | 1150 | | 550 | 1100 | |
| ɯ̀ɨt | 550 | 1500 | | 600 | 1400 | | 550 | 1400 | | 550 | 1350 | |
| tɯ̀ɨt | 600 | 1450 | | 550 | 1450 | | 550 | 1450 | | 550 | 1400 | |
| lɯ̀ɨt | 550 | 1450 | | 550 | 1400 | | 550 | 1450 | | 550 | 1500 | |
| mɯ̀ɨt | 600 | 1600 | | 550 | 1550 | | 550 | 1500 | | 550 | 1550 | |
| ɯ̀ɨk | 550 | 1250 | | 600 | 1300 | | 550 | 1250 | | 550 | 1150 | |
| tɯ̀ɨk | 600 | 1200 | | 600 | 1250 | | 600 | 1250 | | 600 | 1300 | |
| kɯ̀ɨk | 550 | 1250 | | 600 | 1250 | | 600 | 1300 | | 550 | 1250 | |
| bɯ̀ɨk | 550 | 1250 | | 500 | 1250 | | 550 | 1250 | | 550 | 1250 | |

Segment [ɨ] with tone [ˉ]

| Word | 1 F1 | F2 | F3 | 2 F1 | F2 | F3 | 3 F1 | F2 | F3 | 4 F1 | F2 | F3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ɯ̄ɨn | 650 | 1500 | | 600 | 1450 | | 600 | 1450 | | 600 | 1400 | |
| kɯ̄ɨŋ | 650 | 1200 | | 650 | 1200 | | 600 | 1200 | | 600 | 1200 | |
| lɯ̄ɨŋ | 650 | 1300 | | 600 | 1250 | | 650 | 1200 | | 600 | 1200 | |
| ɲɯ̄ɨŋ | 650 | 1200 | | 600 | 1250 | | 650 | 1300 | | 650 | 1300 | |
| zɯ̄ɨŋ | 650 | 1250 | | 600 | 1250 | | 600 | 1250 | | 600 | 1200 | |

Segment [ɨ] with tone [ˈ]

| Word | 1 F1 | F2 | F3 | 2 F1 | F2 | F3 | 3 F1 | F2 | F3 | 4 F1 | F2 | F3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| dɯ̄ɨm | 650 | 1100 | | 650 | 1150 | | 650 | 1150 | | 650 | 1200 | |
| lɯ̄ɨm | 600 | 1150 | | 650 | 1150 | | 600 | 1150 | | 600 | 1150 | |
| lɯ̄ɨn | 650 | 1400 | | 650 | 1350 | | 650 | 1400 | | 650 | 1400 | |
| mɯ̄ɨn | 650 | 1450 | | 650 | 1450 | | 650 | 1450 | | 650 | 1500 | |
| vɯ̄ɨn | 650 | 1400 | | 650 | 1500 | | 650 | 1500 | | 600 | 1500 | |
| tɯ̄ɨŋ | 700 | 1250 | | 700 | 1250 | | 650 | 1250 | | 650 | 1200 | |
| lɯ̄ɨŋ | 650 | 1250 | | 650 | 1250 | | 650 | 1200 | | 650 | 1250 | |
| ɲɯ̄ɨŋ | 700 | 1250 | | 700 | 1200 | | 700 | 1300 | | 700 | 1250 | |
| ŋɯ̄ɨŋ | 700 | 1250 | | 700 | 1250 | | 700 | 1250 | | 700 | 1250 | |
| cɯ̄ɨt | 600 | 1350 | | 650 | 1350 | | 600 | 1350 | | 600 | 1350 | |
| mɯ̄ɨt | 600 | 1500 | | 650 | 1450 | | 600 | 1450 | | 600 | 1450 | |
| vɯ̄ɨt | 600 | 1400 | | 600 | 1500 | | 600 | 1450 | | 650 | 1500 | |
| zɯ̄ɨt | 600 | 1350 | | 550 | 1450 | | 550 | 1500 | | 550 | 1400 | |
| dɯ̄ɨk | 650 | 1250 | | 600 | 1250 | | 600 | 1250 | | 600 | 1250 | |
| ɲɯ̄ɨk | 650 | 1250 | | 600 | 1200 | | 550 | 1250 | | 600 | 1200 | |
| ŋɯ̄ɨk | 700 | 1250 | | 650 | 1250 | | 650 | 1250 | | 650 | 1200 | |

Blank spaces indicate where precise measurements were not obtainable.

FIGURE 14

[ɨ] in closed syllables

All tones Informant 4

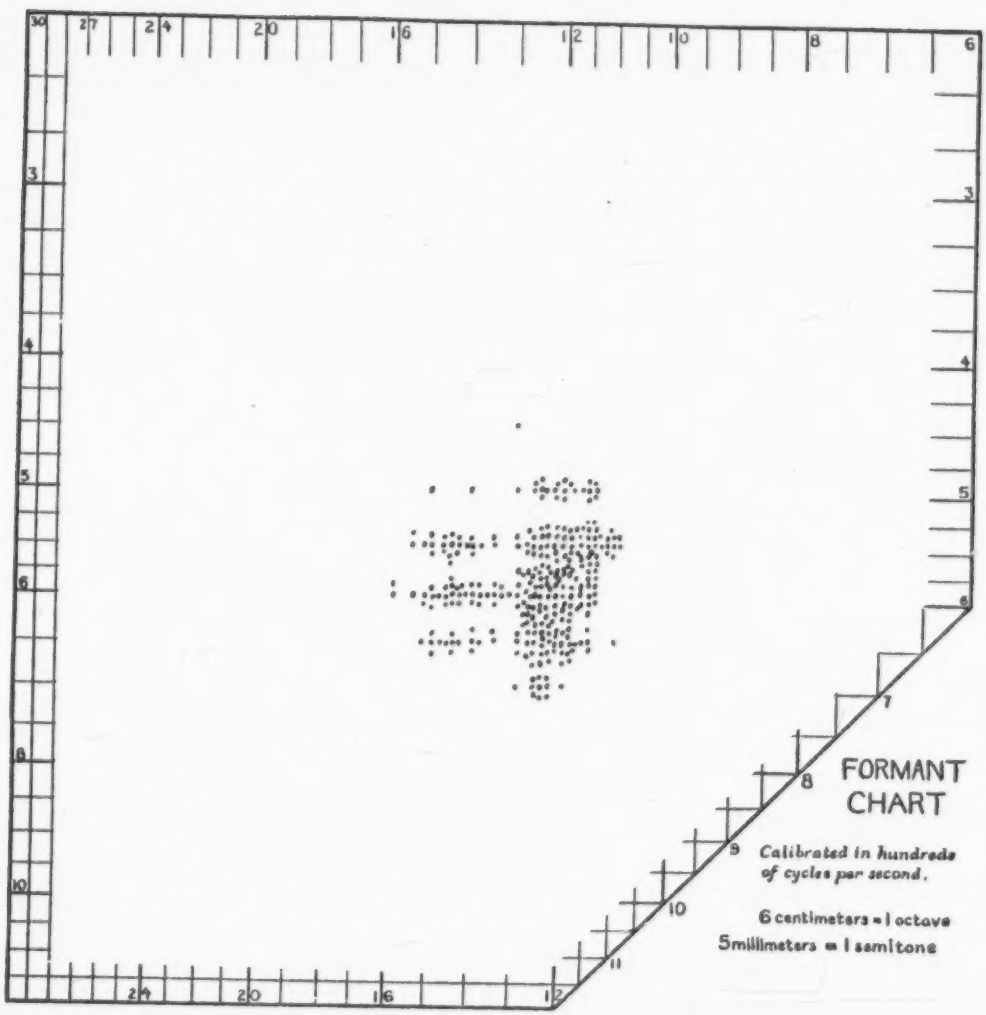


TABLE 15

Formant measurements of complex nuclei segment [ə] Closed syllable cycles/second

All tones Informant 4

Segment [ə] with tone [-]

| Word | 1 F1 | F2 | F3 | 2 F1 | F2 | F3 | 3 F1 | F2 | F3 | 4 F1 | F2 | F3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| cūə̄m | | | | 450 | 850 | | 450 | 1000 | | 450 | 1000 | |
| pūə̄ | | | | 400 | 1000 | | 400 | 1000 | | 450 | 1000 | |
| tūə̄n | | | | 450 | 1100 | | 450 | 1150 | | 450 | 1150 | |
| $t^h$ūə̄n | | | | 450 | 1100 | | 450 | 1150 | | 450 | 1000 | |
| būə̄n | | | | 450 | 1150 | | 450 | 1100 | | 450 | 1100 | |
| lūə̄n | | | | 500 | 1150 | | 450 | 1050 | | 400 | 1000 | |
| mūə̄n | | | | 450 | 1100 | | 400 | 1050 | | 500 | 1050 | |
| [illegible] | | | | 550 | 1000 | | 500 | 1000 | | 500 | 950 | |
| cūə̄ŋ | | | | 500 | 1000 | | 500 | 1000 | | 450 | 950 | |
| $t^h$ūə̄ŋ | | | | 500 | 1100 | | 450 | 1000 | | 450 | 900 | |
| lūə̄ŋ | | | | 450 | 900 | | 450 | 1000 | | 450 | 1000 | |
| cūə̄ŋ | | | | 450 | 1000 | | 450 | 1000 | | 450 | 900 | |
| nūə̄ŋ | | | | 450 | 900 | | 450 | 1000 | | 450 | 1000 | |

Segment [ə] with tone [ˇ]

| Word | 1 F1 | F2 | F3 | 2 F1 | F2 | F3 | 3 F1 | F2 | F3 | 4 F1 | F2 | F3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| nūə̌m | | | | 400 | 750 | | 350 | 850 | | 350 | 800 | |
| kūə̌n | | | | 550 | 1050 | | 500 | 1100 | | 500 | 1050 | |
| mūə̌n | | | | 450 | 950 | | 450 | 950 | | 550 | 950 | |
| úə̌ŋ | | | | 450 | 850 | | 450 | 850 | | 500 | 850 | |
| kúə̌ŋ | | | | 550 | 950 | | 500 | 950 | | 500 | 950 | |
| múə̌ŋ | | | | 500 | 950 | | 500 | 900 | | 450 | 800 | |
| húə̌ŋ | | | | 450 | 900 | | 450 | 850 | | 450 | 1000 | |
| túə̌t | | | | 400 | 1150 | | 400 | 1100 | | 500 | 1100 | |
| cúə̌t | | | | 400 | 1150 | | 450 | 1100 | | 450 | 1150 | |
| búə̌t | | | | 350 | 1050 | | 350 | 1000 | | 350 | 1050 | |
| núə̌t | | | | 450 | 1150 | | 400 | 1050 | | 350 | 1150 | |
| $t^h$úə̌k | | | | 450 | 900 | | 350 | 850 | | 450 | 900 | |
| kúə̌k | | | | 400 | 1150 | | 400 | 1150 | | 400 | 1100 | |
| dúə̌k | | | | 500 | 800 | | 500 | 800 | | 450 | 900 | |
| gúə̌k | | | | 450 | 950 | | 450 | 1000 | | 450 | 1050 | |

Segment [ə] with tone [ˋ]

| Word | 1 F1 | F2 | F3 | 2 F1 | F2 | F3 | 3 F1 | F2 | F3 | 4 F1 | F2 | F3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| bùə̀m | | | | 500 | 1000 | | 500 | 950 | | 450 | 850 | |
| tùə̀n | | | | 550 | 1200 | | 550 | 1200 | | 500 | 1150 | |
| cùə̀n | | | | 500 | 1150 | | 500 | 1150 | | 550 | 1150 | |
| lùə̀n | | | | 450 | 1100 | | 500 | 1100 | | 500 | 1100 | |
| ŋùə̀n | | | | 500 | 1100 | | 500 | 1100 | | 550 | 1050 | |
| tùə̀ŋ | | | | 500 | 1000 | | 500 | 950 | | 500 | 950 | |
| kùə̀ŋ | | | | 500 | 1100 | | 500 | 1050 | | 500 | 1050 | |
| lùə̀ŋ | | | | 500 | 900 | | 500 | 950 | | 450 | 1000 | |
| bùə̀ŋ | | | | 500 | 1000 | | 550 | 1050 | | 500 | 1050 | |

Segment [ə] with tone [ˆ]

| Word | 1 F1 | F2 | F3 | 2 F1 | F2 | F3 | 3 F1 | F2 | F3 | 4 F1 | F2 | F3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| kūə̂m | | | | 550 | 900 | | 500 | 850 | | 500 | 850 | |
| mūə̂m | | | | 500 | 850 | | 500 | 950 | | 500 | 800 | |
| mūə̂ŋ | | | | 500 | 950 | | 500 | 950 | | 500 | 850 | |

Segment [ə] with tone [¯]

| Word | 1 F1 | F2 | F3 | 2 F1 | F2 | F3 | 3 F1 | F2 | F3 | 4 F1 | F2 | F3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| nūə̄m | | | | 550 | 850 | | 500 | 850 | | 500 | 850 | |
| kūə̄n | | | | 550 | 1150 | | 500 | 1150 | | 550 | 1100 | |
| mūə̄n | | | | 500 | 1150 | | 500 | 1100 | | 550 | 1150 | |
| gūə̄n | | | | 500 | 1200 | | 550 | 1200 | | 500 | 1150 | |
| kūə̄ŋ | | | | 550 | 950 | | 550 | 900 | | 550 | 1000 | |
| zūə̄ŋ | | | | 550 | 950 | | 500 | 900 | | 550 | 1000 | |
| tūə̄t | | | | 450 | 1000 | | 500 | 1100 | | 450 | 1150 | |
| cūə̄t | | | | 500 | 1150 | | 500 | 1200 | | 500 | 1200 | |
| būə̄t | | | | 450 | 1100 | | 450 | 1100 | | 450 | 1050 | |
| zūə̄t | | | | 450 | 1150 | | 500 | 1150 | | 500 | 1100 | |
| $t^h$ūə̄k | | | | 500 | 950 | | 450 | 950 | | 500 | 1000 | |
| cūə̄k | | | | 500 | 1000 | | 550 | 1050 | | 550 | 1050 | |
| kūə̄k | | | | 550 | 1100 | | 500 | 1050 | | 500 | 1050 | |
| būə̄k | | | | 500 | 950 | | 450 | 950 | | 450 | 900 | |
| lūə̄k | | | | 500 | 1050 | | 550 | 1000 | | 500 | 1000 | |

Segment [ə] with tone [˘]

| Word | 1 F1 | F2 | F3 | 2 F1 | F2 | F3 | 3 F1 | F2 | F3 | 4 F1 | F2 | F3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $t^h$ūə̆ŋ | | | | 500 | 950 | | 450 | 950 | | 500 | 950 | |
| sūə̆ŋ | | | | 500 | 900 | | 500 | 950 | | 500 | 1000 | |

Blank spaces indicate where precise measurements were not obtainable.

FIGURE 15

[θ] in closed syllables

All tones Informant 4

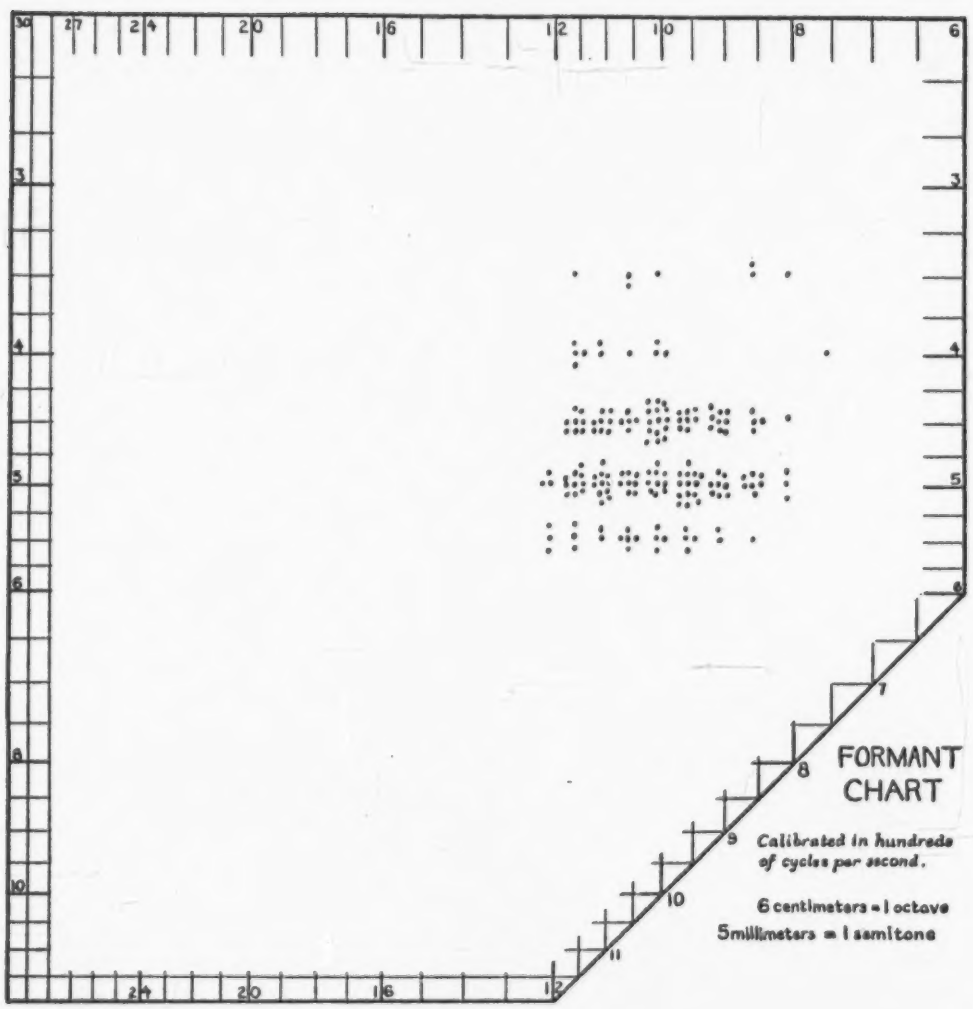
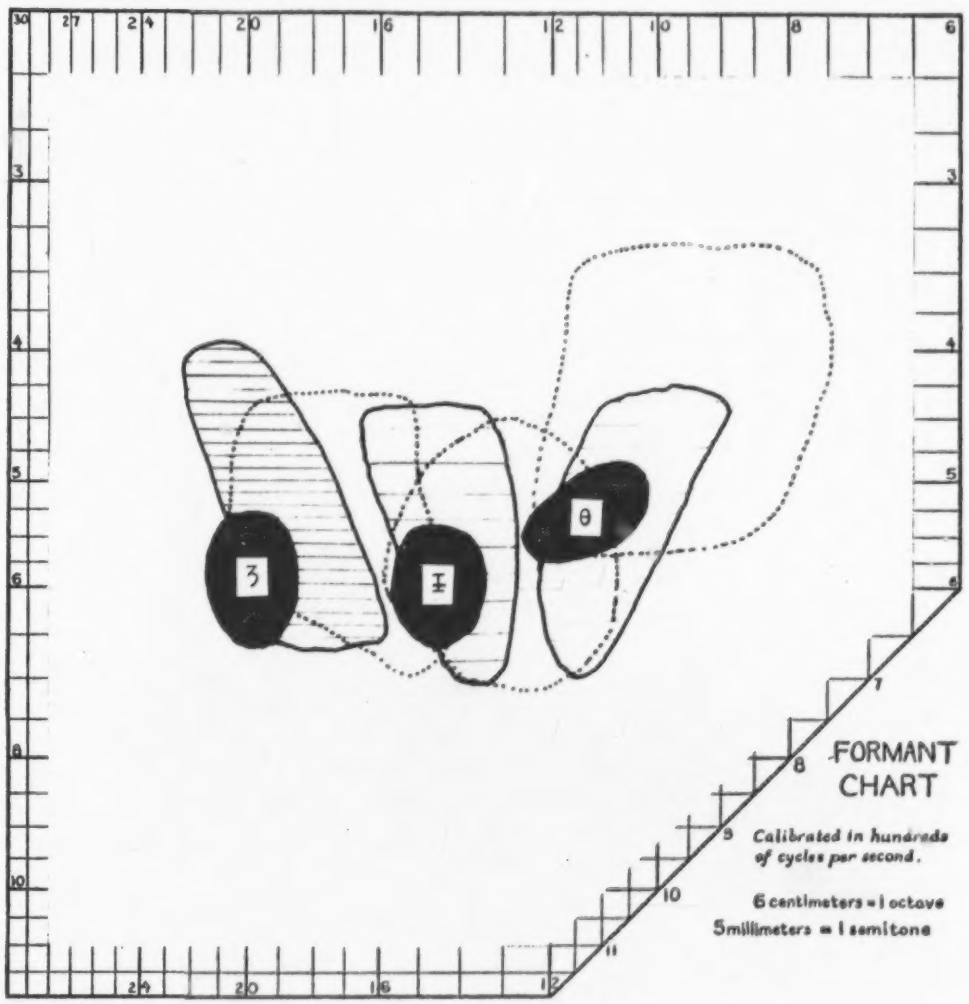


FIGURE 15a

Comparison of [ʒ] [ɪ] and [θ]

Various environments Informant 4



with /-m, -n, -ŋ, -p, -t, -k/ as final consonants, with all six tones.

As was demonstrated in the preceeding chapter and as is seen here, the domains of the nuclei segments [ɜ], [ɨ], and [ə] are clearly separated in a restricted environment such as [t-n] with level tone. When the environment is expanded to include all six tones, but restricted to open syllable types, the domains of [ɜ], [ɨ], and [ə] are still clearly distinct from one another. When the environment is expanded to include closed syllables and all tones, overlap of the three domains does occur; but, this overlap is in a regular pattern, i.e., the domains move backward on the formant chart.

To check and augment our data, we examined and analysed the recorded material of Informant 3 according to the same procedures used with that of Informant 4. Tables 16, 17, and 18 are the measurements of Informant 3's [ɜ], [ɨ], and [ə], respectively, in open syllables, including all tones. Figures 16, 17, and 18 are the corresponding graphic representations on formant charts.

Figure 18a presents the domains occupied by [ɜ], [ɨ], and [ə] in open syllables on one formant chart. Although Informant 3's [ɨ] and [ə] show some marginal overlap, [ɜ] is clearly separated and in general, three domains can be identified.

TABLE 16

**Formant measurements of complex nuclei segment [ɻ] Open syllable cycles/second**

All tones Informant 3

Segment [ɻ] with tone [-]

| Word | 1 F1 | F2 | F3 | 2 F1 | F2 | F3 | 3 F1 | F2 | F3 | 4 F1 | F2 | F3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| tɪ̄ɻ̄ | 750 | 1800 | | 700 | 1750 | | 700 | 1850 | | 700 | 1700 | |
| tʰɪ̄ɻ̄ | 750 | 1750 | | 700 | 1800 | | 700 | 1700 | | 650 | 1850 | |
| cɪ̄ɻ̄ | 700 | 1750 | | 650 | 1800 | | 700 | 1800 | | 700 | 1800 | |
| kɪ̄ɻ̄ | 700 | 1800 | | 700 | 1900 | | 700 | 1900 | | 650 | 1900 | |
| tɪ̄ɻ̄ | 700 | 1850 | | 700 | 1900 | | 650 | 1850 | | 650 | 1850 | |
| lɪ̄ɻ̄ | 700 | 1750 | | 700 | 1900 | | 700 | 1900 | | 700 | 1850 | |
| nɪ̄ɻ̄ | 700 | 1900 | | 650 | 1900 | | 650 | 1850 | | 650 | 1850 | |
| nɪ̄ɻ̄ | 700 | 2000 | | 550 | 2000 | | 650 | 1900 | | 550 | 2100 | |
| vɪ̄ɻ̄ | 700 | 1950 | | 700 | 1950 | | 650 | 1850 | | 650 | 2050 | |
| zɪ̄ɻ̄ | 550 | 2000 | | 700 | 1950 | | 650 | 1950 | | 550 | 2000 | |
| hɪ̄ɻ̄ | 600 | 1800 | | 550 | 2000 | | 550 | 2000 | | 550 | 1900 | |

Segment [ɻ] with tone [ˊ]

| Word | 1 F1 | F2 | F3 | 2 F1 | F2 | F3 | 3 F1 | F2 | F3 | 4 F1 | F2 | F3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| tɪ́ɻ̄ | | | | 750 | 1950 | | 750 | 1900 | | 750 | 1950 | |
| mɪ́ɻ̄ | | | | 800 | 1950 | | 750 | 1850 | | 750 | 1850 | |
| fɪ́ɻ̄ | | | | 750 | 1800 | | 750 | 1850 | | 700 | 1900 | |
| xɪ́ɻ̄ | | | | 750 | 1850 | | 750 | 1950 | | 750 | 1950 | |

Segment [ɻ] with tone [ˇ]

| Word | 1 F1 | F2 | F3 | 2 F1 | F2 | F3 | 3 F1 | F2 | F3 | 4 F1 | F2 | F3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| cɪ̌ɻ̄ | | | | 900 | 1750 | | 800 | 1800 | | 750 | 1900 | |
| kɪ̌ɻ̄ | | | | 800 | 1900 | | 800 | 1900 | | 750 | 1850 | |
| bɪ̌ɻ̄ | | | | 800 | 1750 | | 850 | 1750 | | 750 | 1800 | |
| dɪ̌ɻ̄ | | | | 850 | 1800 | | 800 | 1800 | | 800 | 1800 | |
| lɪ̌ɻ̄ | | | | 850 | 1850 | | 850 | 1750 | | 800 | 1850 | |

Segment [ɻ] with tone [ˋ]

| Word | 1 F1 | F2 | F3 | 2 F1 | F2 | F3 | 3 F1 | F2 | F3 | 4 F1 | F2 | F3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| cɪ̀ɻ̄ | | | | 900 | 1850 | | 850 | 1950 | | 850 | 1900 | |
| dɪ̀ɻ̄ | | | | 850 | 1900 | | 850 | 1850 | | 800 | 1950 | |
| nɪ̀ɻ̄ | | | | 850 | 1900 | | 850 | 1850 | | 800 | 1850 | |
| ɳɪ̀ɻ̄ | | | | 850 | 1950 | | 850 | 1850 | | 850 | 1850 | |

Segment [ɻ] with tone [ˇ]

| Word | 1 F1 | F2 | F3 | 2 F1 | F2 | F3 | 3 F1 | F2 | F3 | 4 F1 | F2 | F3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ɪ̌ɻ̄ | 850 | 1700 | | 850 | 1700 | | 850 | 1700 | | 800 | 1750 | |
| tɪ̌ɻ̄ | 900 | 1700 | | 900 | 1700 | | 850 | 1800 | | 850 | 1800 | |
| dɪ̌ɻ̄ | 900 | 1650 | | 900 | 1750 | | 850 | 1750 | | 800 | 1800 | |
| mɪ̌ɻ̄ | 850 | 1650 | | 850 | 1700 | | 800 | 1750 | | 800 | 1800 | |

Segment [ɻ] with tone [¯]

| Word | 1 F1 | F2 | F3 | 2 F1 | F2 | F3 | 3 F1 | F2 | F3 | 4 F1 | F2 | F3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| bɪ̄ɻ̄ | 850 | 1950 | | 850 | 1900 | | 850 | 2000 | | 850 | 1900 | |
| dɪ̄ɻ̄ | 850 | 1900 | | 850 | 1900 | | 800 | 1950 | | 800 | 1950 | |
| lɪ̄ɻ̄ | 850 | 1850 | | 800 | 1900 | | 850 | 1850 | | 850 | 1950 | |

**Blank spaces indicate where precise measurements were not obtainable.**

FIGURE 16

[ʒ] in open syllables

All tones Informant 3

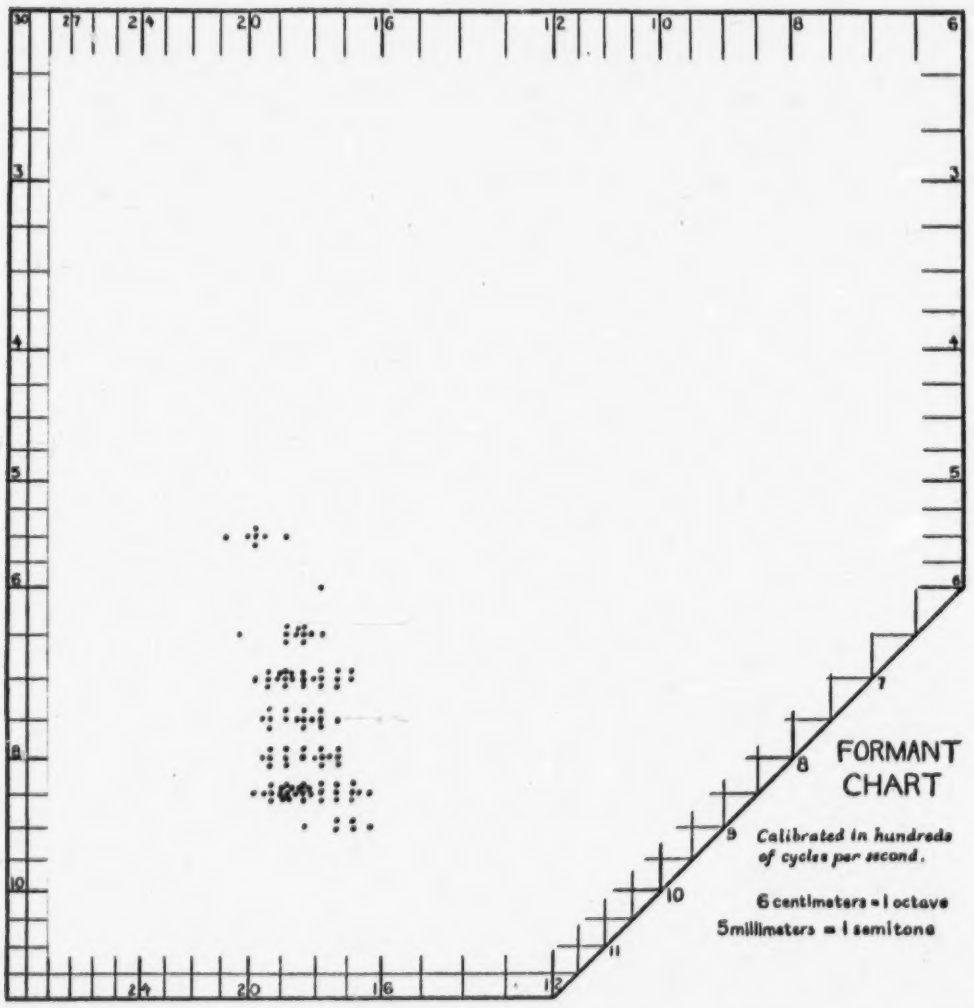


TABLE 17

Formant measurements of complex nuclei segment [ɤ] Open syllable cycles/second

All tones Informant 3

Segment [ɤ] with tone [-]

| Word | 1 F1 | F2 | F3 | 2 F1 | F2 | F3 | 3 F1 | F2 | F3 | 4 F1 | F2 | F3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ɤ̄ | 500 | 1350 | | 650 | 1300 | | 600 | 1250 | | 600 | 1250 | |
| tʰɤ̄ | 650 | 1300 | | 600 | 1250 | | 600 | 1250 | | 600 | 1200 | |
| cɤ̄ | 700 | 1350 | | 700 | 1350 | | 650 | 1350 | | 650 | 1300 | |
| dɤ̄ | 650 | 1300 | | 650 | 1250 | | 600 | 1250 | | 650 | 1350 | |
| mɤ̄ | 550 | 1300 | | 650 | 1250 | | 650 | 1250 | | 650 | 1250 | |
| sɤ̄ | 650 | 1300 | | 650 | 1250 | | 650 | 1250 | | 650 | 1250 | |
| zɤ̄ | 650 | 1300 | | 500 | 1300 | | 650 | 1300 | | 650 | 1250 | |

Segment [ɤ] with tone [ˊ]

| Word | 1 F1 | F2 | F3 | 2 F1 | F2 | F3 | 3 F1 | F2 | F3 | 4 F1 | F2 | F3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| cɤ́ | | | | 650 | 1300 | | 650 | 1300 | | 650 | 1300 | |
| kɤ́ | | | | 750 | 1300 | | 650 | 1300 | | 650 | 1350 | |
| bɤ́ | | | | 700 | 1400 | | 650 | 1350 | | 650 | 1350 | |
| dɤ́ | | | | 650 | 1350 | | 650 | 1300 | | 600 | 1350 | |
| lɤ́ | | | | 650 | 1350 | | 650 | 1250 | | 600 | 1450 | |
| mɤ́ | | | | 750 | 1250 | | 650 | 1250 | | 500 | 1250 | |
| nɤ́ | | | | 650 | 1300 | | 650 | 1400 | | 600 | 1450 | |
| ŋɤ́ | | | | 600 | 1350 | | 600 | 1350 | | 600 | 1450 | |
| hɤ́ | | | | 650 | 1300 | | 650 | 1300 | | 600 | 1250 | |

Segment [ɤ] with tone [ˇ]

| Word | 1 F1 | F2 | F3 | 2 F1 | F2 | F3 | 3 F1 | F2 | F3 | 4 F1 | F2 | F3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| cɤ̌ | | | | 800 | 1400 | | 750 | 1400 | | 750 | 1350 | |
| bɤ̌ | | | | 750 | 1400 | | 750 | 1350 | | 750 | 1350 | |
| lɤ̌ | | | | 750 | 1450 | | 750 | 1400 | | 750 | 1400 | |
| ŋɤ̌ | | | | 750 | 1350 | | 750 | 1350 | | 750 | 1400 | |

Segment [ɤ] with tone [ˋ]

| Word | 1 F1 | F2 | F3 | 2 F1 | F2 | F3 | 3 F1 | F2 | F3 | 4 F1 | F2 | F3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| cɤ̀ | | | | 800 | 1500 | | 800 | 1500 | | 750 | 1500 | |
| bɤ̀ | | | | 800 | 1400 | | 850 | 1450 | | 850 | 1500 | |
| nɤ̀ | | | | 800 | 1450 | | 800 | 1450 | | 800 | 1450 | |

Segment [ɤ] with tone [ˇˋ]

| Word | 1 F1 | F2 | F3 | 2 F1 | F2 | F3 | 3 F1 | F2 | F3 | 4 F1 | F2 | F3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| cɤ̌ˋ | | | | 850 | 1350 | | 850 | 1400 | | 800 | 1400 | |
| kɤ̌ˋ | | | | 850 | 1400 | | 800 | 1450 | | 800 | 1450 | |
| bɤ̌ˋ | | | | 850 | 1450 | | 850 | 1400 | | 850 | 1400 | |
| mɤ̌ˋ | | | | 900 | 1450 | | 900 | 1400 | | 850 | 1400 | |
| nɤ̌ˋ | | | | 850 | 1500 | | 800 | 1500 | | 800 | 1500 | |
| ŋɤ̌ˋ | | | | 850 | 1500 | | 850 | 1450 | | 850 | 1500 | |

Segment [ɤ] with tone [¬]

| Word | 1 F1 | F2 | F3 | 2 F1 | F2 | F3 | 3 F1 | F2 | F3 | 4 F1 | F2 | F3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ɤ̄ | | | | 750 | 1350 | | 750 | 1350 | | 750 | 1350 | |
| tɤ̄ | | | | 750 | 1400 | | 750 | 1350 | | 750 | 1350 | |
| kɤ̄ | | | | 750 | 1350 | | 750 | 1350 | | 750 | 1400 | |
| bɤ̄ | | | | 750 | 1400 | | 750 | 1350 | | 750 | 1350 | |
| lɤ̄ | | | | 800 | 1400 | | 800 | 1400 | | 750 | 1350 | |
| ŋɤ̄ | | | | 750 | 1350 | | 750 | 1300 | | 750 | 1350 | |

Blank spaces indicate where precise measurements were not obtainable.

FIGURE 17

[ɪ] in open syllables

All tones Informant 3

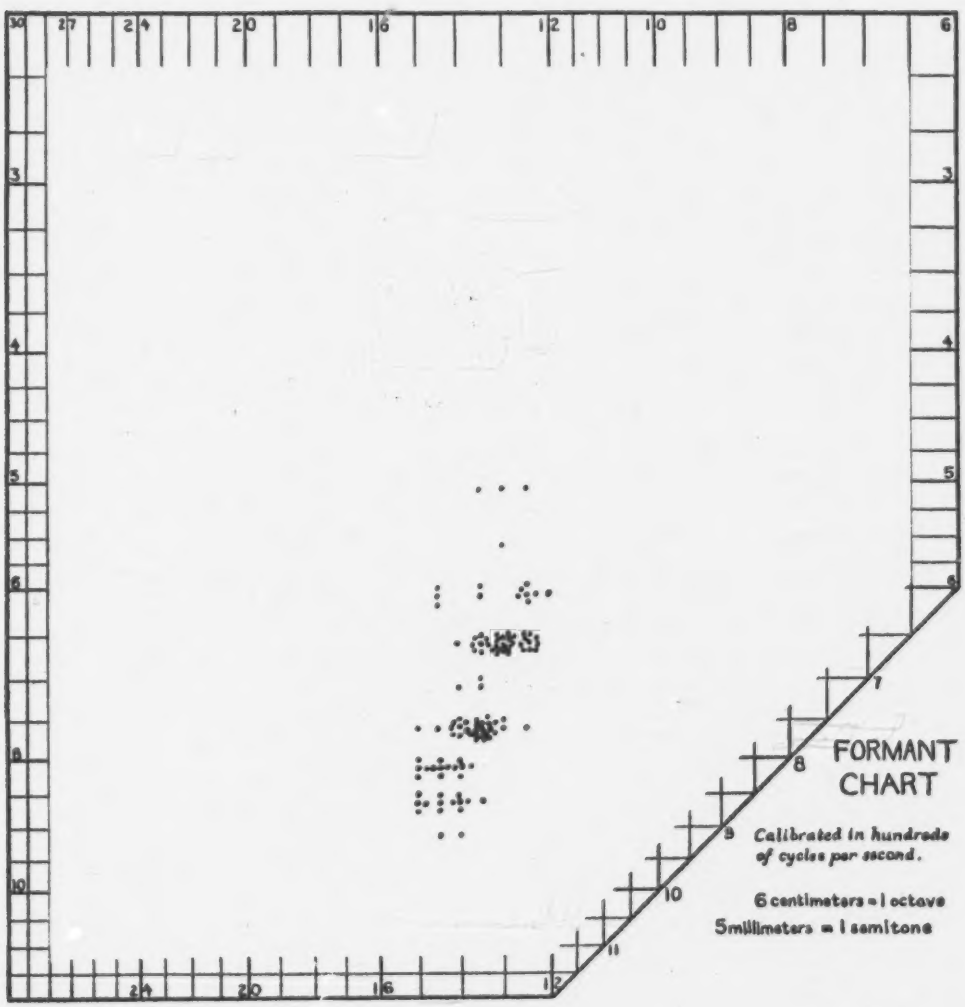


TABLE 18

Formant measurements of complex nuclei segment [ə] Open syllable cycles/second

All tones Informant 3

Segment [ə] with tone [-]

| Word | 1 F1 | F2 | F3 | 2 F1 | F2 | F3 | 3 F1 | F2 | F3 | 4 F1 | F2 | F3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| tʰū̄ə | 700 | 1150 | | 700 | 1200 | | 750 | 1250 | | 700 | 1200 | |
| tū̄ə | 750 | 1250 | | 700 | 1200 | | 700 | 1200 | | 700 | 1200 | |
| dū̄ə | 650 | 1250 | | 700 | 1200 | | 600 | 1200 | | 600 | 1200 | |
| dū̄ə | 650 | 1050 | | 750 | 1250 | | 750 | 1250 | | 700 | 1200 | |
| nū̄ə | 500 | 1000 | | 600 | 1200 | | 600 | 1200 | | 500 | 1200 | |
| ŋū̄ə | 500 | 1050 | | 500 | 1000 | | 500 | 1000 | | 500 | 1100 | |
| fū̄ə | 600 | 1100 | | 600 | 1100 | | 600 | 1200 | | 600 | 1100 | |
| vū̄ə | 700 | 1150 | | 700 | 1150 | | 700 | 1150 | | 700 | 1150 | |
| sū̄ə | 600 | 1100 | | 600 | 1100 | | 600 | 1200 | | 500 | 1200 | |
| zū̄ə | 500 | 1000 | | 600 | 1100 | | 600 | 1150 | | 600 | 1150 | |
| xū̄ə | 600 | 1000 | | 600 | 1200 | | 600 | 1150 | | 600 | 1200 | |

Segment [ə] with tone [/]

| Word | 1 F1 | F2 | F3 | 2 F1 | F2 | F3 | 3 F1 | F2 | F3 | 4 F1 | F2 | F3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ū́ə | | | | 550 | 1050 | | 600 | 1050 | | 600 | 1100 | |
| tū́ə | | | | 650 | 1000 | | 600 | 1000 | | 600 | 1000 | |
| cū́ə | | | | 600 | 1000 | | 600 | 1200 | | 600 | 1200 | |
| bū́ə | | | | 500 | 1000 | | 600 | 950 | | 450 | 950 | |
| lū́ə | | | | 600 | 1000 | | 600 | 1200 | | 550 | 1150 | |
| mū́ə | | | | 600 | 1000 | | 600 | 950 | | 600 | 1100 | |

Segment [ə] with tone [ˇ]

| Word | 1 F1 | F2 | F3 | 2 F1 | F2 | F3 | 3 F1 | F2 | F3 | 4 F1 | F2 | F3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| nə̌ | | | | 650 | 1050 | | 650 | 1100 | | 650 | 1100 | |
| cə̌ə | | | | 750 | 1200 | | 650 | 1200 | | 650 | 1200 | |
| bə̌ə | | | | 650 | 1100 | | 650 | 1100 | | 650 | 1100 | |
| də̌ə | | | | 650 | 1150 | | 750 | 1200 | | 650 | 1150 | |
| lə̌ə | | | | 750 | 1200 | | 700 | 1150 | | 700 | 1200 | |
| mə̌ə | | | | 650 | 1100 | | 600 | 1050 | | 600 | 1150 | |

Segment [ə] with tone [~]

| Word | 1 F1 | F2 | F3 | 2 F1 | F2 | F3 | 3 F1 | F2 | F3 | 4 F1 | F2 | F3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| dū̃ə | 700 | 1250 | | 750 | 1200 | | 750 | 1250 | | 750 | 1250 | |
| lū̃ə | 750 | 1300 | | 750 | 1200 | | 750 | 1250 | | 750 | 1250 | |
| zū̃ə | | | | 700 | 1200 | | 750 | 1300 | | 750 | 1250 | |

Segment [ə] with tone [v]

| Word | 1 F1 | F2 | F3 | 2 F1 | F2 | F3 | 3 F1 | F2 | F3 | 4 F1 | F2 | F3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ū̆ə | 850 | 1200 | | 800 | 1250 | | 750 | 1150 | | 800 | 1150 | |
| kū̆ə | | | | 850 | 1200 | | 750 | 1200 | | 800 | 1150 | |
| zū̆ə | | | | 800 | 1200 | | 850 | 1300 | | 850 | 1250 | |

Segment [ə] with tone [—]

| Word | 1 F1 | F2 | F3 | 2 F1 | F2 | F3 | 3 F1 | F2 | F3 | 4 F1 | F2 | F3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ū̄ə | 750 | 1200 | | 750 | 1250 | | 750 | 1150 | | 750 | 1150 | |
| bū̄ə | 750 | 1200 | | 750 | 1150 | | 700 | 1200 | | 700 | 1150 | |
| lū̄ə | 750 | 1200 | | 750 | 1250 | | 750 | 1250 | | 700 | 1200 | |

Blank spaces indicate where precise measurements were not obtainable.

FIGURE 18

[ə] in open syllables

All tones Informant 3

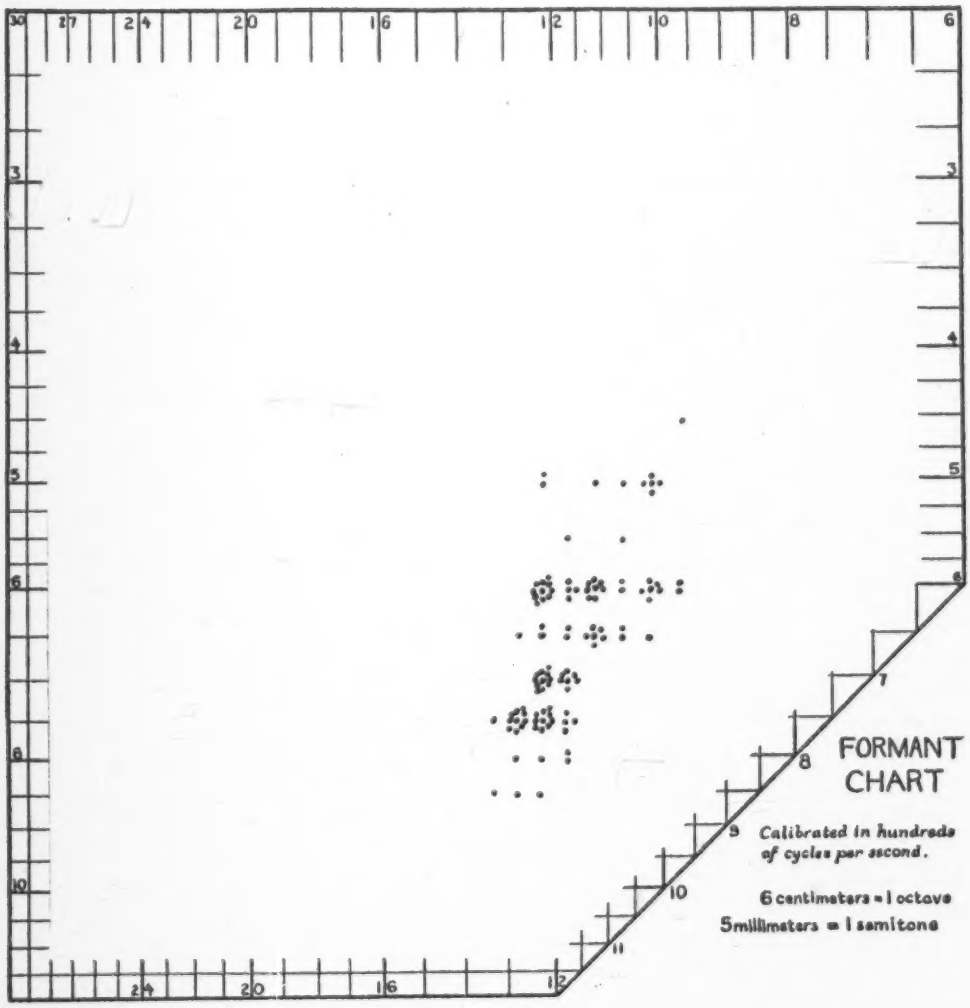
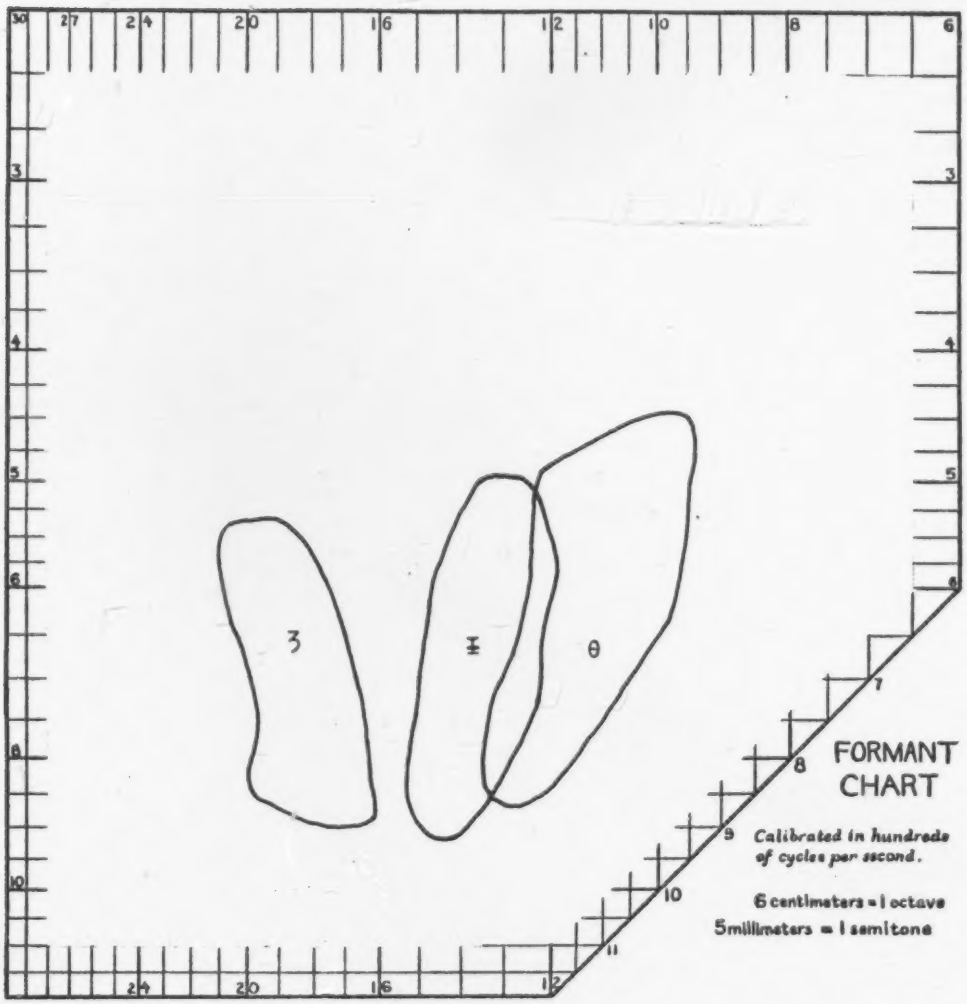


FIGURE 18a

Domains of [-ʒ] [-ɪ] [-θ] in open syllables

All tones Informant 3



Tables 19, 20, and 21 are the measurements of the three segments [ɜ], [ɪ], and [ə] of Informant 3 in closed syllables with the final consonants /-m, -n, -ŋ, -p, -t, -k/, including all six tones. Figures 19, 20, and 21 are the corresponding charts.

Figure 21a is the composite chart showing all three nuclei segments in the three environments examined: [t-n] with level tone; open syllable with all tones; and closed syllables with all tones. As with Informant 4, the overlap which is apparent is regularly conditioned with the domains becoming larger and moving further back on the formant chart.

TABLE 19

Formant measurements of complex nuclei segment [ɜ] Closed syllable cycles/second

All tones Informant 3

Segment [ɜ] with tone [-]

| Word | 1 F1 | F2 | F3 | 2 F1 | F2 | F3 | 3 F1 | F2 | F3 | 4 F1 | F2 | F3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ɪɜ̄m | | | | 550 | 1900 | | 550 | 1850 | | 550 | 1900 | |
| tɪɜ̄m | | | | 550 | 1950 | | 550 | 1950 | | 550 | 1850 | |
| kɪɜ̄m | | | | 550 | 1900 | | 550 | 2150 | | 550 | 2000 | |
| lɪɜ̄m | | | | 550 | 1900 | | 550 | 1850 | | 550 | 2100 | |
| nɪɜ̄m | | | | 550 | 1950 | | 550 | 1950 | | 550 | 2050 | |
| ŋɪɜ̄m | | | | 550 | 1900 | | 550 | 1850 | | 550 | 1850 | |
| ɪɜ̄n | | | | 550 | 2250 | | 550 | 2150 | | 550 | 2150 | |
| tɪɜ̄n | | | | 550 | 2050 | | 550 | 1900 | | 550 | 1950 | |
| kɪɜ̄n | | | | 550 | 2200 | | 550 | 2100 | | 550 | 2150 | |
| lɪɜ̄n | | | | 550 | 2150 | | 550 | 2100 | | 550 | 2100 | |
| nɪɜ̄n | | | | 550 | 2150 | | 550 | 2150 | | 550 | 2150 | |
| mɪɜ̄n | | | | 550 | 2250 | | 550 | 2150 | | 550 | 2250 | |
| nɪɜ̄n | | | | 550 | 2150 | | 500 | 2250 | | 500 | 2150 | |
| pɪɜ̄n | | | | 550 | 2200 | | 500 | 2100 | | 500 | 2050 | |
| ŋɪɜ̄n | | | | 500 | 2250 | | 500 | 2100 | | 500 | 2100 | |
| ɪɜ̄ŋ | | | | 500 | 1950 | | 500 | 1950 | | 500 | 1900 | |
| kɪɜ̄ŋ | | | | 550 | 1900 | | 550 | 1850 | | 550 | 2000 | |
| ŋɪɜ̄ŋ | | | | 550 | 1850 | | 550 | 1900 | | 550 | 1900 | |
| tɪɜ̄p | | | | 800 | 1750 | | 800 | 1750 | | 800 | 1750 | |
| ŋɪɜ̄p | | | | 800 | 1850 | | 800 | 1850 | | 800 | 1800 | |
| tɪɜ̄t | | | | 750 | 1950 | | 750 | 2000 | | 750 | 1900 | |
| tʰɪɜ̄t | | | | 800 | 1900 | | 750 | 1900 | | 750 | 2000 | |
| nɪɜ̄t | | | | 750 | 1950 | | 750 | 1950 | | 750 | 2000 | |
| ŋɪɜ̄t | | | | 750 | 2050 | | 800 | 2100 | | 750 | 2000 | |
| tɪɜ̄k | | | | 750 | 1750 | | 800 | 1750 | | 900 | 1750 | |
| vɪɜ̄k | | | | 800 | 1750 | | 800 | 1800 | | 800 | 1750 | |

Segment [ɜ] with tone [˧]

| Word | 1 F1 | F2 | F3 | 2 F1 | F2 | F3 | 3 F1 | F2 | F3 | 4 F1 | F2 | F3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| tɪɜ̀m | | | | 800 | 1850 | | 800 | 1800 | | 800 | 1850 | |
| kɪɜ̀m | | | | 800 | 1850 | | 800 | 1850 | | 750 | 1800 | |
| lɪɜ̀m | | | | 800 | 1750 | | 750 | 1800 | | 800 | 1800 | |
| nɪɜ̀m | | | | 800 | 1800 | | 750 | 1750 | | 750 | 1750 | |
| tɪɜ̀n | | | | 800 | 2000 | | 800 | 1950 | | 800 | 2000 | |
| lɪɜ̀n | | | | 800 | 2000 | | 750 | 1950 | | 750 | 1900 | |
| nɪɜ̀n | | | | 800 | 2150 | | 800 | 2000 | | 750 | 2100 | |

Segment [ɜ] with tone [˩˧]

| Word | 1 F1 | F2 | F3 | 2 F1 | F2 | F3 | 3 F1 | F2 | F3 | 4 F1 | F2 | F3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| tɪɜ̌m | | | | 850 | 1800 | | 800 | 1700 | | 850 | 1800 | |
| tʰɪɜ̌m | | | | 850 | 1750 | | 850 | 1700 | | 850 | 1800 | |
| kɪɜ̌m | | | | 800 | 1800 | | 850 | 1700 | | 750 | 1950 | |
| tʰɪɜ̌n | | | | 850 | 1950 | | 750 | 1900 | | 700 | 2000 | |
| ɪɜ̌ŋ | | | | 900 | 1800 | | 850 | 1700 | | 850 | 1650 | |

Segment [ɜ] with tone [˩]

| Word | 1 F1 | F2 | F3 | 2 F1 | F2 | F3 | 3 F1 | F2 | F3 | 4 F1 | F2 | F3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ɪɜ̗m | | | | 650 | 2100 | | 650 | 2050 | | 650 | 2050 | |
| tɪɜ̗m | | | | 650 | 2100 | | 600 | 2000 | | 600 | 2100 | |
| kɪɜ̗m | | | | 600 | 1950 | | 650 | 2050 | | 600 | 2000 | |
| ɪɜ̗n | | | | 700 | 2150 | | 700 | 2100 | | 700 | 2100 | |
| tɪɜ̗n | | | | 750 | 2200 | | 750 | 2000 | | 750 | 2150 | |
| tɪɜ̗ŋ | | | | 500 | 2050 | | 500 | 2000 | | 600 | 1950 | |
| bɪɜ̗ŋ | | | | 600 | 1950 | | 600 | 1950 | | 600 | 2150 | |
| dɪɜ̗ŋ | | | | 500 | 1950 | | 500 | 1900 | | 500 | 1950 | |
| tɪɜ̗p | | | | 650 | 1850 | | 600 | 1900 | | 600 | 1800 | |
| kɪɜ̗p | | | | 650 | 2000 | | 650 | 1800 | | 700 | 1900 | |
| ɪɜ̗t | | | | 650 | | | 650 | 2050 | | 650 | 2200 | |
| tɪɜ̗t | | | | 700 | 1950 | | 650 | 1950 | | 650 | 1950 | |
| kɪɜ̗t | | | | 650 | 1950 | | 650 | 2000 | | 650 | 2000 | |
| tɪɜ̗k | | | | 700 | 1750 | | 700 | 1750 | | 650 | 1800 | |
| pɪɜ̗k | | | | 700 | 1850 | | 700 | 1800 | | 650 | 1800 | |
| dɪɜ̗k | | | | 750 | 1850 | | 700 | 1750 | | 650 | 1800 | |

Segment [ɜ] with tone [~]

| Word | 1 F1 | F2 | F3 | 2 F1 | F2 | F3 | 3 F1 | F2 | F3 | 4 F1 | F2 | F3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| lɪɜ̰m | | | | 850 | 1850 | | 850 | 1800 | | 800 | 1950 | |
| nɪɜ̰m | | | | 800 | 1900 | | 750 | 1750 | | 750 | 1850 | |
| tɪɜ̰n | | | | 850 | 2050 | | 800 | 2050 | | 800 | 2000 | |
| lɪɜ̰n | | | | 800 | 2100 | | 850 | 2000 | | 800 | 2100 | |
| nɪɜ̰n | | | | 800 | 2100 | | 800 | 2100 | | 750 | 2200 | |
| nɪɜ̰ŋ | | | | 750 | 1900 | | 750 | 1900 | | 750 | 1950 | |

Segment [ɜ] with tone [¯]

| Word | 1 F1 | F2 | F3 | 2 F1 | F2 | F3 | 3 F1 | F2 | F3 | 4 F1 | F2 | F3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| tɪɜ̄m | | | | 800 | 1800 | | 800 | 1900 | | 800 | 1900 | |
| nɪɜ̄m | | | | 800 | 1900 | | 800 | 1950 | | 800 | 1900 | |
| ŋɪɜ̄m | | | | 750 | 1900 | | 800 | 1950 | | 750 | 1950 | |
| tɪɜ̄n | | | | 800 | 1950 | | 800 | 1950 | | 800 | 1900 | |
| tʰɪɜ̄n | | | | 850 | 1950 | | 850 | 1900 | | 850 | 1950 | |
| lɪɜ̄ŋ | | | | 800 | 1850 | | 800 | 1900 | | 800 | 1900 | |

Blank spaces indicate where precise measurements were not obtainable.

FIGURE 19

[ɔ] in closed syllables

All tones Informant 3

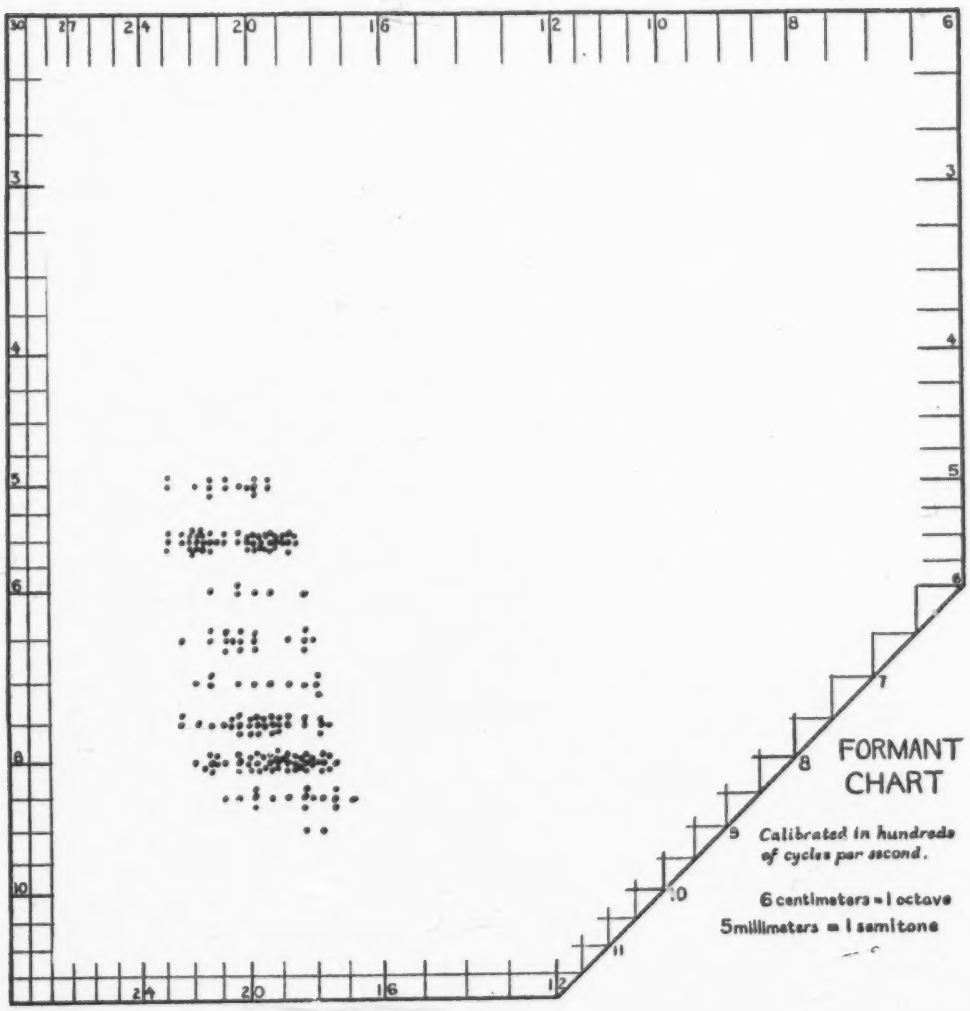


TABLE 20

**Formant measurements of complex nuclei segment [ɨ] Closed syllable cycles/second**

All tones Informant 3

Segment [ɨ] with tone [-]

| Word | 1 F1 | F2 | F3 | 2 F1 | F2 | F3 | 3 F1 | F2 | F3 | 4 F1 | F2 | F3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| tɯ̄m | | | | 600 | 1200 | | 600 | 1200 | | 600 | 1200 | |
| nɯ̄n | | | | 550 | 1350 | | 550 | 1350 | | 550 | 1350 | |
| [illegible] | | | | 600 | 1200 | | 550 | 1250 | | 550 | 1250 | |
| [illegible]n | | | | 500 | 1300 | | 500 | 1400 | | 500 | 1400 | |
| lɯ̄n | | | | 500 | 1400 | | 500 | 1450 | | 550 | 1350 | |
| tɯ̄ŋ | | | | 550 | 1450 | | 550 | 1400 | | 550 | 1350 | |
| cɯ̄ŋ | | | | 550 | 1350 | | 550 | 1350 | | 550 | 1350 | |
| lɯ̄ŋ | | | | 550 | 1400 | | 550 | 1400 | | 550 | 1400 | |
| ɦɯ̄ŋ | | | | 550 | 1400 | | 550 | 1350 | | 500 | 1350 | |
| lɯ̄ŋ | | | | 550 | 1350 | | 500 | 1300 | | 500 | 1300 | |
| nɯ̄ŋ | | | | 550 | 1400 | | 550 | 1400 | | 550 | 1350 | |
| nɯ̄ŋ | | | | 550 | 1350 | | 550 | 1350 | | 550 | 1350 | |

Segment [ɨ] with tone [\]

| Word | 1 F1 | F2 | F3 | 2 F1 | F2 | F3 | 3 F1 | F2 | F3 | 4 F1 | F2 | F3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| cɯ̀m | | | | 750 | 1350 | | 750 | 1450 | | 700 | 1400 | |
| kɯ̀m | | | | 700 | 1350 | | 700 | 1400 | | 750 | 1400 | |
| nɯ̀m | | | | 800 | 1450 | | 750 | 1350 | | 750 | 1350 | |
| zɯ̀m | | | | 700 | 1400 | | 700 | 1350 | | 750 | 1300 | |
| cɯ̀n | | | | 650 | 1500 | | 700 | 1500 | | 700 | 1550 | |
| vɯ̀n | | | | 750 | 1550 | | 750 | 1500 | | 750 | 1600 | |
| sɯ̀n | | | | 750 | 1550 | | 750 | 1550 | | 750 | 1550 | |
| tɯ̀ŋ | | | | 700 | 1400 | | 650 | 1300 | | 650 | 1350 | |
| cɯ̀ŋ | | | | 700 | 1400 | | 650 | 1350 | | 750 | 1300 | |
| lɯ̀ŋ | | | | 650 | 1350 | | 650 | 1350 | | 750 | 1350 | |
| ɦɯ̀ŋ | | | | 650 | 1350 | | 700 | 1400 | | 700 | 1350 | |

Segment [ɨ] with tone [∨]

| Word | 1 F1 | F2 | F3 | 2 F1 | F2 | F3 | 3 F1 | F2 | F3 | 4 F1 | F2 | F3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| tɯ̌ŋ | | | | 700 | 1250 | | 700 | 1250 | | 700 | 1200 | |
| cɯ̌ŋ | | | | 700 | 1250 | | 750 | 1250 | | 750 | 1250 | |
| ɦɯ̌ŋ | | | | 800 | 1250 | | 750 | 1300 | | 750 | 1300 | |

Segment [ɨ] with tone [⌐]

| Word | 1 F1 | F2 | F3 | 2 F1 | F2 | F3 | 3 F1 | F2 | F3 | 4 F1 | F2 | F3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| bɯ̃m | | | | 500 | 1250 | | 500 | 1250 | | 500 | 1250 | |
| mɯ̃n | | | | 500 | 1400 | | 600 | 1500 | | 600 | 1500 | |
| bɯ̃ŋ | | | | 450 | 1200 | | 450 | 1200 | | 450 | 1200 | |
| nɯ̃ŋ | | | | 500 | 1250 | | 500 | 1250 | | 450 | 1200 | |
| hɯ̃ŋ | | | | 500 | 1300 | | 500 | 1300 | | 500 | 1250 | |
| ɯ̃p | | | | 700 | 1350 | | 650 | 1350 | | 650 | 1350 | |
| kɯ̃p | | | | 700 | 1350 | | 700 | 1400 | | 650 | 1350 | |
| ɯ̃t | | | | 650 | 1400 | | 650 | 1450 | | 650 | 1450 | |
| tɯ̃t | | | | 650 | 1350 | | 650 | 1300 | | 650 | 1350 | |
| lɯ̃t | | | | 650 | 1400 | | 600 | 1500 | | 600 | 1500 | |
| ɯ̃k | | | | 700 | 1300 | | 700 | 1300 | | 700 | 1350 | |
| tɯ̃k | | | | 650 | 1300 | | 650 | 1300 | | 650 | 1300 | |
| $t^h$ɯ̃k | | | | 650 | 1300 | | 650 | 1300 | | 650 | 1250 | |
| kɯ̃k | | | | 650 | 1250 | | 650 | 1250 | | 650 | 1250 | |
| bɯ̃k | | | | 650 | 1250 | | 650 | 1250 | | 650 | 1250 | |

Segment [ɨ] with tone [~]

| Word | 1 F1 | F2 | F3 | 2 F1 | F2 | F3 | 3 F1 | F2 | F3 | 4 F1 | F2 | F3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ɯ̃n | | | | 700 | 1650 | | 700 | 1650 | | 700 | 1600 | |
| lɯ̃ŋ | | | | 750 | 1350 | | 750 | 1350 | | 750 | 1300 | |
| kɯ̃ŋ | | | | 750 | 1200 | | 750 | 1300 | | 700 | 1250 | |
| nɯ̃ŋ | | | | 750 | 1250 | | 750 | 1300 | | 700 | 1350 | |

Segment [ɨ] with tone [¬]

| Word | 1 F1 | F2 | F3 | 2 F1 | F2 | F3 | 3 F1 | F2 | F3 | 4 F1 | F2 | F3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| dɯ̄m | | | | 700 | 1450 | | 750 | 1400 | | 750 | 1350 | |
| lɯ̄m | | | | 750 | 1400 | | 750 | 1400 | | 750 | 1350 | |
| lɯ̄n | | | | 700 | 1350 | | 750 | 1400 | | 800 | 1400 | |
| mɯ̄n | | | | 800 | 1450 | | 800 | 1450 | | 800 | 1450 | |
| vɯ̄n | | | | 750 | 1400 | | 750 | 1350 | | 750 | 1400 | |
| tɯ̄ŋ | | | | 750 | 1350 | | 700 | 1350 | | 750 | 1350 | |
| lɯ̄ŋ | | | | 700 | 1300 | | 700 | 1300 | | 700 | 1350 | |
| nɯ̄ŋ | | | | 700 | 1400 | | 750 | 1350 | | 700 | 1400 | |
| cɯ̄t | | | | 800 | 1400 | | 750 | 1350 | | 700 | 1400 | |
| mɯ̄t | | | | 700 | 1400 | | 700 | 1450 | | 700 | 1400 | |
| vɯ̄t | | | | 750 | 1350 | | 750 | 1350 | | 750 | 1350 | |
| zɯ̄t | | | | 750 | 1400 | | 750 | 1400 | | 750 | 1350 | |
| dɯ̄k | | | | 700 | 1250 | | 700 | 1200 | | 700 | 1200 | |
| nɯ̄k | | | | 700 | 1400 | | 700 | 1400 | | 700 | 1400 | |
| ŋɯ̄k | | | | 700 | 1200 | | 700 | 1200 | | 650 | 1150 | |

Segment [ɨ] with tone [⌐]

| Word | 1 F1 | F2 | F3 | 2 F1 | F2 | F3 | 3 F1 | F2 | F3 | 4 F1 | F2 | F3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| [illegible] | | | | 500 | 1250 | | 500 | 1250 | | 500 | 1250 | |
| [illegible] | | | | 500 | 1400 | | 600 | 1500 | | 600 | 1500 | |
| [illegible] | | | | 450 | 1200 | | 450 | 1200 | | 450 | 1200 | |
| [illegible] | | | | 500 | 1250 | | 500 | 1250 | | 450 | 1200 | |
| [illegible] | | | | 500 | 1300 | | 500 | 1300 | | 500 | 1250 | |
| [illegible] | | | | 700 | 1350 | | 650 | 1350 | | 650 | 1350 | |
| [illegible] | | | | 700 | 1350 | | 700 | 1400 | | 650 | 1350 | |
| [illegible] | | | | 650 | 1400 | | 650 | 1450 | | 650 | 1450 | |
| [illegible] | | | | 650 | 1350 | | 650 | 1300 | | 650 | 1350 | |
| [illegible] | | | | 650 | 1400 | | 600 | 1500 | | 600 | 1500 | |
| [illegible] | | | | 700 | 1300 | | 700 | 1300 | | 700 | 1350 | |
| [illegible] | | | | 650 | 1300 | | 650 | 1300 | | 650 | 1300 | |
| [illegible] | | | | 650 | 1300 | | 650 | 1300 | | 650 | 1250 | |
| [illegible] | | | | 650 | 1250 | | 650 | 1250 | | 650 | 1250 | |
| [illegible] | | | | 650 | 1250 | | 650 | 1250 | | 650 | 1250 | |

Segment [ɨ] with tone [~]

| Word | 1 F1 | F2 | F3 | 2 F1 | F2 | F3 | 3 F1 | F2 | F3 | 4 F1 | F2 | F3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| [illegible] | | | | 700 | 1650 | | 700 | 1650 | | 700 | 1600 | |
| [illegible] | | | | 750 | 1350 | | 750 | 1350 | | 750 | 1300 | |
| [illegible] | | | | 750 | 1200 | | 750 | 1300 | | 700 | 1250 | |
| [illegible] | | | | 750 | 1250 | | 750 | 1300 | | 700 | 1350 | |

Segment [ɨ] with tone [¬]

| Word | 1 F1 | F2 | F3 | 2 F1 | F2 | F3 | 3 F1 | F2 | F3 | 4 F1 | F2 | F3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| [illegible] | | | | 700 | 1450 | | 750 | 1400 | | 750 | 1350 | |
| [illegible] | | | | 750 | 1400 | | 750 | 1400 | | 750 | 1350 | |
| [illegible] | | | | 700 | 1350 | | 750 | 1400 | | 800 | 1400 | |
| [illegible] | | | | 800 | 1450 | | 800 | 1450 | | 800 | 1450 | |
| [illegible] | | | | 750 | 1400 | | 750 | 1350 | | 750 | 1400 | |
| [illegible] | | | | 750 | 1350 | | 700 | 1350 | | 750 | 1350 | |
| [illegible] | | | | 700 | 1300 | | 700 | 1300 | | 700 | 1350 | |
| [illegible] | | | | 700 | 1400 | | 750 | 1350 | | 700 | 1400 | |
| [illegible] | | | | 800 | 1400 | | 750 | 1350 | | 700 | 1400 | |
| [illegible] | | | | 700 | 1400 | | 700 | 1450 | | 700 | 1400 | |
| [illegible] | | | | 750 | 1350 | | 750 | 1350 | | 750 | 1350 | |
| [illegible] | | | | 750 | 1400 | | 750 | 1400 | | 750 | 1350 | |
| [illegible] | | | | 700 | 1250 | | 700 | 1200 | | 700 | 1200 | |
| [illegible] | | | | 700 | 1400 | | 700 | 1400 | | 700 | 1400 | |
| [illegible] | | | | 700 | 1200 | | 700 | 1200 | | 650 | 1150 | |

**Blank spaces indicate where precise measurements were not obtainable.**

FIGURE 20

[ɨ] in closed syllables

All tones Informant 3

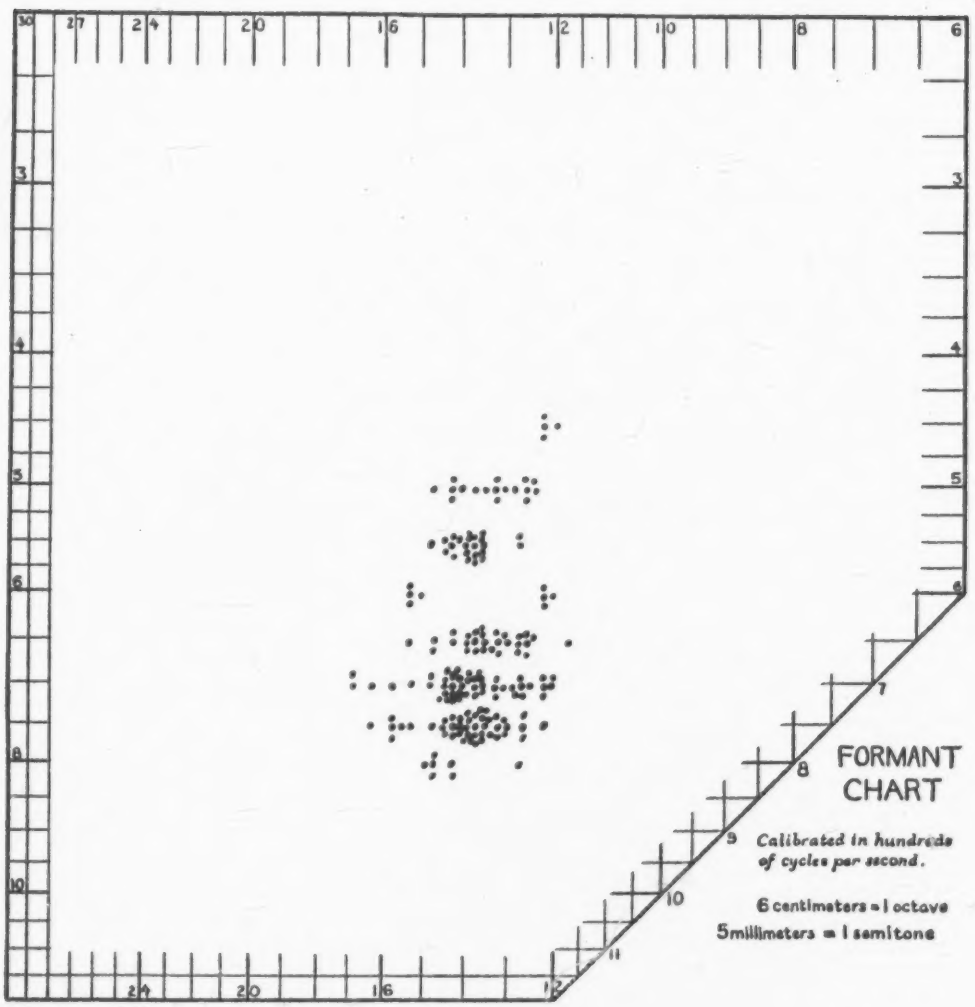


TABLE 21

**Formant measurements of complex nuclei segment [ə] Closed syllable cycles/second**

All tones Informant 3

Segment [ə] with tone [-]

| Word | 1 F1 | F2 | F3 | 2 F1 | F2 | F3 | 3 F1 | F2 | F3 | 4 F1 | F2 | F3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| cūən | | | | 500 | 1100 | | 500 | 1050 | | 500 | 1050 | |
| pūən | | | | 550 | 1050 | | 500 | 1050 | | 500 | 1050 | |
| tūən | | | | 500 | 1300 | | 500 | 1300 | | 500 | 1250 | |
| tʰūən | | | | 500 | 1300 | | 500 | 1300 | | 500 | 1300 | |
| būən | | | | 500 | 1300 | | 500 | 1300 | | 500 | 1300 | |
| lūən | | | | 500 | 1300 | | 500 | 1300 | | 500 | 1300 | |
| nūən | | | | 500 | 1350 | | 500 | 1350 | | 500 | 1300 | |
| gūəŋ | | | | 500 | 1050 | | 500 | 1000 | | 500 | 1000 | |
| cūəŋ | | | | 500 | 1050 | | 500 | 1000 | | 500 | 1000 | |
| būəŋ | | | | 450 | 950 | | 500 | 1000 | | 500 | 1050 | |
| lūəŋ | | | | 500 | 1050 | | 500 | 1000 | | 500 | 1050 | |
| nūəŋ | | | | 500 | 1050 | | 500 | 1000 | | 500 | 1000 | |

Segment [ə] with tone [ˇ]

| Word | 1 F1 | F2 | F3 | 2 F1 | F2 | F3 | 3 F1 | F2 | F3 | 4 F1 | F2 | F3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| bùən | | | | 600 | 1000 | | 600 | 1000 | | 550 | 1050 | |
| tùən | | | | 600 | 1300 | | 600 | 1300 | | 600 | 1350 | |
| cùən | | | | 650 | 1500 | | 650 | 1350 | | 650 | 1300 | |
| lùən | | | | 600 | 1350 | | 650 | 1300 | | 650 | 1350 | |
| tùəŋ | | | | 600 | 1000 | | 650 | 950 | | 650 | 1000 | |
| bùəŋ | | | | 600 | 1000 | | 650 | 1000 | | 650 | 1050 | |
| lùəŋ | | | | 600 | 1000 | | 650 | 1000 | | 650 | 1050 | |

Segment [ə] with tone [ˇ]

| Word | 1 F1 | F2 | F3 | 2 F1 | F2 | F3 | 3 F1 | F2 | F3 | 4 F1 | F2 | F3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| tʰǔəŋ | | | | 700 | 1100 | | 700 | 1150 | | 700 | 1100 | |
| sǔəŋ | | | | 700 | 1050 | | 700 | 1050 | | 650 | 1050 | |

Segment [ə] with tone [/]

| Word | 1 F1 | F2 | F3 | 2 F1 | F2 | F3 | 3 F1 | F2 | F3 | 4 F1 | F2 | F3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| púəm | | | | 450 | 950 | | 450 | 950 | | 450 | 950 | |
| kúən | | | | 450 | 1250 | | 450 | 1250 | | 450 | 1250 | |
| múən | | | | 500 | 1250 | | 500 | 1200 | | 450 | 1200 | |
| úəŋ | | | | 450 | 950 | | 450 | 950 | | 450 | 950 | |
| cúəŋ | | | | 450 | 1000 | | 450 | 1000 | | 500 | 1000 | |
| múəŋ | | | | 450 | 950 | | 450 | 950 | | 450 | 1000 | |
| húəŋ | | | | 450 | 950 | | 450 | 950 | | 450 | 950 | |
| túət | | | | 600 | 1250 | | 600 | 1250 | | 600 | 1250 | |
| cúət | | | | 650 | 1300 | | 650 | 1250 | | 600 | 1200 | |
| búət | | | | 600 | 1250 | | 600 | 1200 | | 600 | 1250 | |
| núət | | | | 600 | 1250 | | 550 | 1250 | | 600 | 1250 | |
| tʰúək | | | | 600 | 1000 | | 650 | 950 | | 700 | 1050 | |
| kúək | | | | 650 | 1050 | | 650 | 1000 | | 650 | 1000 | |
| dúək | | | | 650 | 1000 | | 650 | 950 | | 650 | 950 | |
| gúək | | | | 700 | 1000 | | 700 | 1050 | | 650 | 1000 | |

Segment [ə] with tone [~]

| Word | 1 F1 | F2 | F3 | 2 F1 | F2 | F3 | 3 F1 | F2 | F3 | 4 F1 | F2 | F3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| kūəm | | | | 650 | 1200 | | 650 | 1150 | | 650 | 1200 | |
| mūəm | | | | 700 | 1200 | | 700 | 1250 | | 700 | 1250 | |
| mūəŋ | | | | 650 | 1000 | | 650 | 1050 | | 700 | 1100 | |

Segment [ə] with tone [¬]

| Word | 1 F1 | F2 | F3 | 2 F1 | F2 | F3 | 3 F1 | F2 | F3 | 4 F1 | F2 | F3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| puəm | | | | 700 | 1250 | | 750 | 1250 | | 700 | 1200 | |
| kuən | | | | 700 | 1350 | | 700 | 1350 | | 700 | 1350 | |
| muən | | | | 750 | 1350 | | 750 | 1300 | | 750 | 1300 | |
| guən | | | | 650 | 1300 | | 700 | 1400 | | 700 | 1400 | |
| kuəŋ | | | | 700 | 1100 | | 650 | 1150 | | 600 | 1100 | |
| suəŋ | | | | 700 | 1200 | | 700 | 1250 | | 700 | 1200 | |
| tuət | | | | 700 | 1300 | | 700 | 1300 | | 700 | 1350 | |
| cuət | | | | 700 | 1300 | | 750 | 1350 | | 750 | 1350 | |
| buət | | | | 600 | 1250 | | 700 | 1300 | | 700 | 1250 | |
| zuət | | | | 650 | 1300 | | 650 | 1250 | | 600 | 1250 | |
| tʰuək | | | | 700 | 1000 | | 650 | 1050 | | 650 | 1100 | |
| cuək | | | | 700 | 1100 | | 750 | 1150 | | 650 | 1050 | |
| kuək | | | | 650 | 1050 | | 700 | 1100 | | 700 | 1200 | |
| buək | | | | 700 | 1100 | | 700 | 1100 | | 650 | 1050 | |
| luək | | | | 700 | 1100 | | 650 | 1150 | | 700 | 1150 | |

Blank spaces indicate where precise measurements were not obtainable.

FIGURE 21

[ɜ] in closed syllables

All tones Informant 3

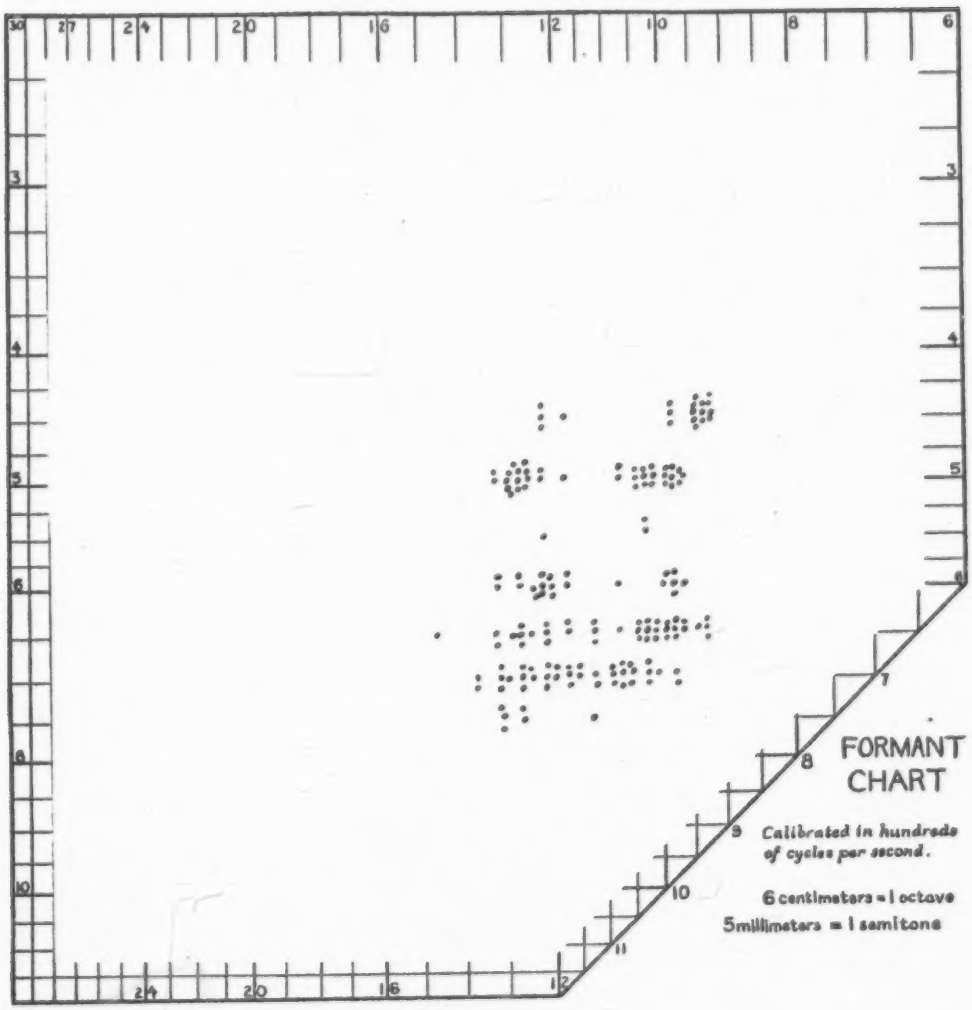
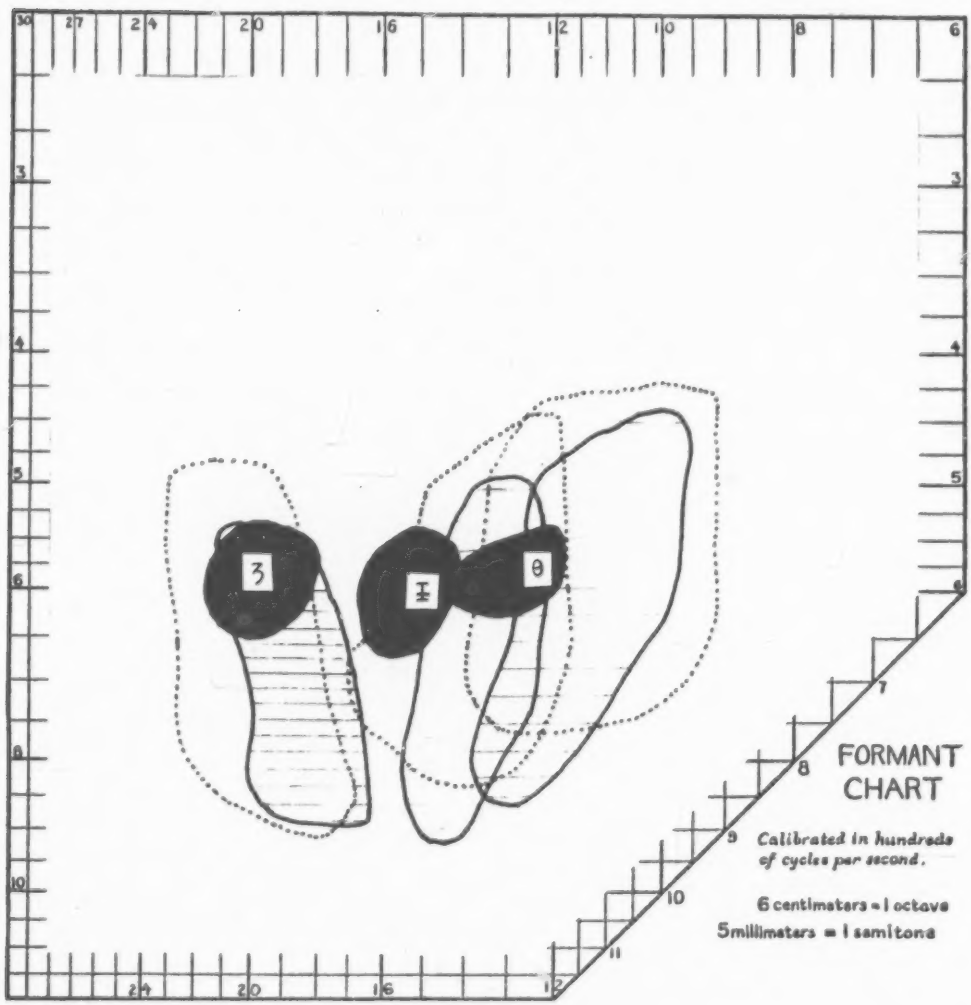


FIGURE 21a

Comparison of [ʒ] [ɪ̈] and [θ]

Various environments Informant 3



## CONCLUSIONS

After carefully considering all the data presented, we came to several conclusions regarding Vietnamese complex nuclei.

1) In Chapter 3, it was established that the first segments of the complex nuclei [Iɜ], [ɯɪ], and [Uθ] could be clearly assigned to the phonemes /i/, /ɯ/, and /u/. It was then demonstrated that the analysis of [ɜ], [ɪ], and [θ] as the three separate phonemes /e/, /ə/, and /o/ was that most consistent with the phonetic phenomena. Experiments with the complex nuclei in more varied environments as delineated in Chapter 4 support this analysis as a valid one.

2) With regard to the question of whether the difference between the sequences spelled "-ia", "-uə", "-ua" in final position and "-iê-", "-uə̯-", "-uô-" in medial position are so great that they should be considered as two different phonemes, we can say that our preliminary phonetic transcription of [Iɜ], [ɯɪ], and [Uθ] for both sequences is supported. Although the location of the domains are shifted slightly backward in closed syllables, they maintain a relative distinctiveness, and the differences among the domains in closed syllables are comparable to those in open syllables. If [ɜ], [ɪ], and [θ] are demonstrated as being three different vocalic qualities in

open syllables, they should be so analysed in closed syllables. In closed syllables or open, spelled "-ia", "-uə̀a", "-ua", or "-iə̂-", "-uə̀-", "-uô-", our phonetic interpretation of these complex nuclei as [iɜ], [wɪ], [uθ] is adequately supported by the acoustic data.

3) We also noted that tone and consonant influence on the complex nuclei is very similar to that observed on the simple vowels /e/, /ə/, and /o/. As was mentioned earlier, there are also distributional characteristics associated with /y/ and /w/ that make [ɜ] similar to /e/, [θ] similar to /o/, and [ɪ] different from /e/ and /o/ and more similar to /ə/.

Therefore, it is our conclusion that the complex syllable nuclei are best analysed with [ɜ] as an allophone of /e/, [ɪ] as an allophone of /ə/, and [θ] as an allophone of /o/, making the complex nuclei phonemically /ie/, /wə/, and /uo/.

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A phonetic and phonemic analysis of the three complex nuclei of Vietnamese (Hanoi dialect) spelled (1) yê-, -iê-, -ia, (2) -ươ-, -ưa, (3) -uô-, -ua, was carried out, using the sound spectrograph. The relative domains of the target qualities of the complex nuclei were established and then compared with those of the eleven simple vowels. The first segments of the complex nuclei were easily established as being the same as /i/, /ɯ/, and /u/. The second segments, which have been variously analysed, were found to occupy three distinct domains which led to our analysis of them as phonemically /e/, /ə/, and /o/. Further analysis was done, varying the environment with regard to type of syllable, tone, initial and final consonants. Regardless of environment, a relative distinctiveness of domain seems to be maintained and this, together with distributional characteristics, supports our final phonemic analysis of the complex nuclei as /ie/, /ɯə/, and /uo/.

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|---|---|---|---|---|---|---|
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